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THE RELATION BETWEEN CERTAIN RIVER TERRACES AND THE GLACIAL SERIES IN NORTHWESTERN CALIFORNIA.

INTRODUCTION.

By a reconnaissance trip in February, 1903, the writer traced a definite system of river terraces between the coast at Humboldt Bay and the Summerville basin on the border of a high mountain cluster which was extensively glaciated in the Pleistocene period and still possesses three tiny glaciers. The importance of connecting the terrace system with the glacial series was recognized and the writer devoted some days to a detailed study of the extremely rocky and brushy canyon, seven miles in length, which separates the Summerville basin from undoubted deposits of the last great glacial stage. The work was greatly facilitated by the operations of the early placer miners, who have beautifully exposed most of the remnants of old channels. It is believed that this study was rewarded by exceptional success, of the truth of which the reader may judge by perusal of the following pages:

I have now discriminated in this region six distinct channel levels (including the present river bed) which, to facilitate the discussion, I will classify by letters, beginning with the highest. In my descriptions I distinguish constantly between "terrace" and "channel." Ordinarily each terrace consists of

a rock bench with a flattened or channeled, water-worn surface (the channel level) overlaid by 5 to 20 feet of river gravel and this by a variable thickness of sandy clay and angular local rock débris, the surface of which constitutes the terrace level. Therefore, the height which I may give for a channel level is always less than that of the corresponding terrace level. Where mining has been carried on extensively, it is often difficult to determine the original surface level of the deposit, but where there has been no mining, the terrace level is the conspicuous feature. The channel is by far the most constant and safest guide to follow as the terrace level is locally raised by torrent fans from neighboring gulches.

The South Fork of Salmon River, in this region, has a nearly straight course (minor deflections excepted) from east to west, being controlled by the predominant joint system of the hornblende schist into which it has trenched a narrow valley, 3,500 feet in depth. It has migrated southward with the dip of the joints. In consequence, the channel remnants occur predominantly on the north side of the river. On the south of the river, back of the immediately overlooking peaks, there is a group of higher peaks, including Mt. Thompson (altitude 9,345 feet) and Mt. Courtney (altitude about 8,800 feet). Within the shadow of these peaks, there are a number of *cirques*, each of which, in the glacial period, was the gathering ground of an independent glacier.

CHANNEL REMNANTS FROM SUMMERVILLE TO BIG BEND BASIN.

The channel which comes up through the gorge below Summerville at a height of 30 to 50 feet, upon entering the Summerville basin seems to separate into two strands, of which the first becomes lower, relative to the river, partly because of partial filling of the channel by tailings, and spreads out to a bench, on the north side of the stream, several hundred feet wide (Channel E). Back of it, and apparently 15 or 20 feet higher, there is another broad shallow channel (Channel D). As we travel up through the basin, we find this latter occurring at 30 to 40 feet above the river, on both sides. The canyon in it is unusually

wide and contains important remnants of the lower terrace. These two lower terraces have dark and light brown débris over the channel gravels proper, but no decided reddish tint. All higher terraces are characterized by a bright red color of the upper dirt layers.

Channel D seems to be the equivalent of the "lower terrace" or "broad valley floor," described elsewhere from the basins on the lower Klamath and lower Trinity rivers, and Channel E is a local development, scarcely occurring anywhere below Cecilville. Channel F is mostly buried under the gravel and bowlders of the present river bed.

At the upper end of the Summerville basin, at the mouth of Rush Creek, there is a very well defined terrace whose surface is at the outer edge about 100 feet above the river. It is well marked along the opposite side of the river as a rather sharp bench. On the north side, facing the river, it has been mined extensively, showing that under its sloping surface there are buried two distinct channels. The outer (Channel C) contained a very bowldery gravel bed from 20 to 30 feet deep, and the inner (Channel B) a similar but thinner and less coarse bed. Most of the bowlders are of the granite of the area on which it rests and from up Rush Creek. A few are of Courtney granite and there are rare small bowlders of serpentine, both from the main valley. The granite bowlders in places are thickly packed. Many are rotten to the center although three feet thick. The red stain in places extends from the surface to a depth of 20 feet. The deposit appears old. It rests on rotten granite. There is a fairly well defined granite platform about 75 feet above the river and a similar platform 30 to 40 feet higher. The sloping surface over these two channels is the main upper terrace of the Summerville basin, but seems to correspond to an intermediate terrace of the system studied nearer the coast.

Channel A is represented by a small river deposit occurring at about 250 feet above the river, just below the Summerville buildings. It is much older than any subsequent channel and the space between its level and that of the main upper terrace is characterized in many places by a peculiar rolling topography

developed in rock. This high channel represents the floor of a comparatively broad valley, of which only a very few remnants remain. It dates back at least as far as the Red Bluff epoch. There are no traces of any higher river deposit in this region.

The valley carved below the main upper terrace at the mouth of Rush Creek may be 500 to 800 feet wide. In it are two main terraces, both well defined. The lower is 15 to 20 feet above the river level, and is trenched by the winding canyon of the present river, which is here several times as wide as the low-water stage of the stream because the soft granite erodes easily. The second terrace may be 50 feet above the river. These two lower terraces have fewer and less rotten large granite bowlders than those higher.

At Miller's suspension bridge the terraces, here well defined, are at about 20, 55 and 120 feet respectively. The rock is harder and the lower canyon getting smaller. The river next swings into the north bluff, cutting away the terrace system but leaving it well defined on the south side. The next swing is into the south bluff and cuts it out on that side.

From here to Big Bend Creek, the north side of the valley contained abundant remnants of the main upper terrace, which have nearly everywhere been mined off. The gravel layer was thin and contained few large bowlders. Over it there was, in the first remnants, 10 to 20 feet of indistinctly stratified local débris such as in the torrent fan at Cooper's mine (but less coarse) discussed in another paper[1] and the significance of which will come out later in this. In places it contains much clay and is red in color. The surface of this terrace sloped distinctly toward the river, but its rock bench, in so far as it constitutes Channel C is level. The latter is well defined on four points and stands about 75 feet above the river. One can look across these points and see that there is absolute correspondence in height of the flat rock platforms.

The rocks are here hard hornblende schist and the canyon narrow from the upper terrace level down, but in it there are

[1] "Some Evidence of Two Glacial Stages in the Klamath Mountains in California," *American Geologist*, Vol. XXXI, March, 1903.

several beautiful remnants of the middle terrace (Channel D), half way down to the river. There is no room for the lower terrace. Above Channel C there seem to be several remnants of a level 30 or 40 feet above it (Channel B). Still higher there is a little channel about 30 feet wide, with a distinct outer rim of bed-rock, a few bowlders and a little gravel in the channel and this overlaid by about 20 feet of red, indistinctly stratified, rather subangular local débris. This may occur nearly 175 feet above the river and probably approximately represents Channel A. Far below it is the main upper terrace.

Just below Big Bend Creek, the covering of the regular river gravel in the main upper terrace by brown, not red, distinctly stratified and partly water-worn hornblende schist pebbles and subangular débris, as in Cooper's mine, becomes quite apparent. This is the downstream edge of the torrent fan of Crosby Creek, elsewhere discussed, and it is here 20 to 40 feet thick. It buries two channels. At 65 feet above the river we have the floor of Channel C, which from here upstream becomes the main or best developed upper channel. We know that it is Channel C because this is one of the four points just mentioned, and we can see that it absolutely corresponds to the channel which, farther down stream, stands at 75 feet above the river. The canyon is getting shallower. Channel D occurs on the opposite (south) side of the river at only 20 feet above the stream.

Channel C contains some large bowlders of Courtney granite and the regular river deposit is covered by about 40 feet of the Crosby Creek alluvium. Just back of it we have at 80 feet above the river, Channel B, which contains few large bowlders and is covered by a less thickness of the Crosby Creek alluvium. It is quite evident that the mass of local débris which came with a rush of water down Crosby Gulch and was distributed down the valley and stratified by the river, rests on nothing lower than Channel C of the Summerville basin. It is of the same age as the completion of this channel and it is the equivalent of the local débris which nearly everywhere seems to form the surface deposit of the main upper terrace of the Summerville basin and gives it its sloping surface. Its relation to Channel B is simply

that there was such an abundance of material that it succeeded also in submerging the higher channel remnants.

At the mouths of Big Bend and Grizzly creeks, a belt of chlorite schist enabled the excavation of a basin about 1,000 feet square. The river makes a large bend around by the south, and descends rapidly, so that the terraces are higher above the stream on the downstream than the upstream side. In the east central portion of the basin there was a flat whose surface rose about 30 feet above the river on the upstream side, and whose bed-rock floor rises 10 to 15 feet above the same portion of the river. This is Channel D and the gravel was not covered by the local alluvium. On its downstream side there is a broad terrace rising 12 feet above the river. On the other side of the river there is a terrace whose bed-rock floor is 10 to 15 feet above the river and surface 20 to 25 feet above the stream. There is no local alluvium on it. It seems to be the last development upstream of Channel E. Back of it there is a marked remnant of a terrace whose bed-rock floor seems to be about 75 feet above the river. The surface is possibly 100 feet above the river. Within the canyon at the lower end of Big Bend basin, remnants of this channel occur on both sides of the river and lead directly to the last discussed development of Channel C. Similarly, the next lower channel occurs in the gorge as a long narrow bench on the north side, with rock floor 20 feet above the river.

At the mouth of Big Bend Creek there is an alluvial fan apparently made by that stream. It rests on the same bed-rock surface as the "15-foot channel" (Channel D) which is 25 feet above the river at the downstream end of the basin. The gravel is 65 feet thick and remarkable for the many large granite bowlders of Big Bend granite, some of which are so large that it seems incredible that the Big Bend Creek could have carried them. The surface is rough and bowldery, and sloped distinctly toward the river. Some features indicate a glacial origin but the deposit seems waterlaid. The age is the same as that of the gravel of Channel D.

FROM BIG BEND BASIN TO COOPER'S MINE.

Between the Big Bend and Little South Fork creeks, there are several marked remnants of the main channel (Channel C), crossing points on the inner side of curves in a new course of the river. The local alluvium which was deeply piled over the regular river deposit, displaced the river repeatedly and compelled it to take a somewhat serpentine course. Consequently the new canyon is not everywhere directly under the old.

At the upper end of Big Bend basin, Channel C has a height above the river of only 50 feet, but is clearly seen to be the same level as the 75-foot channel at the lower end of the basin. Small remnants of this 50-foot channel occur on each rock point on the south side of the river for some distance upstream. Below them there is a long narrow bench of the 15-foot channel (Channel D). On the first prominent point on the north side, the main channel is 50 feet above the river, but at 70 feet there is another channel (Channel B). Both of them were buried under the stratified local débris, the lower the deeper. On the same point occurs a marked remnant of the 15-foot channel, which was not buried under local débris.

The next point on the south of the river has a marked remnant of the main old channel whose floor is here 55 feet above the river. There is a distinct outer rim. The new canyon is 75 feet (minimum) in depth. Over the old channel gravel there is at least 40 feet of local stratified alluvial débris (including that of the Crosby Creek fan). There is also a remnant of the higher channel.

The next point on the north side of the river has a narrow remnant of the old channel system. It is about 50 feet above the river and is distinctly higher than the main channel remnants on the south points both above and below this point. Hence it represents Channel B. There is not much local débris left over it.

The next point on the south side of the river, which is a short distance below Little South Fork Creek, has an important remnant of Channel C. Its rock floor is 75 feet above the river, it has a distinct outer rim, and the new channel has been cut

into solid rock 100 feet deep as a minimum. Over the gravel there was stratified local débris 30 to 40 feet thick.

The slight variation in height above the river, of the different remnants of a given channel is due to the facts that the river always has had a variable grade because of harder and softer rock belts and that the present higher grade and lower grade sections do not quite correspond with those of the past. As a matter of fact, the older channels were better graded than is the present river bed.

In ascending the river from Summerville, Channel C gradually approaches the present river level and the new canyon, at first thought, might appear to be smaller. In reality, I have found, to my surprise, that the river everywhere has accomplished about the same amount of cutting in rock of a given hardness. The new canyon above Big Bend basin is largely excavated to one or the other side of the old course and includes the removal of considerable rock above the level of Channel C.

Along the old Spooner ditch on the north side of the valley, overlooking the old channel remnant just described, there is an area of gravel about 1500 feet in length and 100 to 200 feet in width. Its lower edge seems to be about 300 feet above the river, and it ranges to at least 100 feet higher. Near the western end it seems to rest on a bed-rock slope of 10° to 20°, much less than the slope above or below. The ditch is cut into it for several hundred yards to a depth of about 10 feet and splendidly exposes its interior. It is a heterogeneous agglomeration of bowlders and pebbles and subangular rock fragments embedded in a grayish (partly brown stained) sandy clay. There is no sorting of the material and not a trace of stratification. Its general appearance is that of a glacial deposit, but it is so old and rotten that if any striae existed they have been destroyed by decay.

The larger bowlders are chiefly of hornblende schist from the subjacent terrane, Courtney granite from near the head of the river and massive serpentine. The latter are plentiful enough to be conspicuous. Bowlders 18 inches to 2 feet in diameter are found without much difficulty. The largest bowlder observed is

a serpentine 4 × 4 × 5 feet. The remarkable feature of this serpentine constituent is that serpentine does not occur in place anywhere in the basin of the *old* Salmon River between this point and its head. The evident source of these bowlders is a serpentine area on the eastern side of the *old* Coffee Creek valley, within several miles of its head. That portion of the *old* Coffee Creek valley has been captured and is now drained by Salmon River. A study of the gorge at the head of the *old* Salmon River valley indicates that the beheading occurred late in the glacial period, that is, was associated with one of the later glacial stages as will appear later in this paper. Salmon River now has access to the serpentine and is bringing a small percentage of serpentine pebbles and cobbles below the gorge, but they are soon worn out so that at the distance of three miles from the gorge they are extremely rare in the present river deposit. One so rarely finds a specimen of them in the old channels up to this deposit under discussion, that they may be considered practically absent. Why are they so characteristically abundant in this higher and older gravel? I have but one plausible explanation of it. A glacier headed in the *old* Coffee Creek valley, overrode the col at the head of this valley and sent a shallow tongue far beyond any point reached by subsequent glaciations—three miles farther down the valley than the distinct glacial moraines to be described later, and to a locality now but 3,700 feet above the sea.

Whether this is a glacial or a river deposit, I am going to refer its level to Channel A. I am going to show traces of the same deposit for several miles up the valley at nearly a uniform level. They seem to have been deposited on the valley floor where it joined the steeper mountain slope. Therefore, I consider them to represent the level of the valley floor of that time in much the same way as do the old channel deposits.

In this deposit along the Spooner ditch all the granite bowlders are thoroughly rotted to the core. So they are in certain portions of the lower channels. But here other rock species which are not usually much decayed in the river channels, fall to dust. Various porphyries, diorites, gabbros, and schists will not

bear handling. The serpentine bowlders are hard, but pitted and honey-combed. Even the hornblende schist, which is one of our most resistant rocks, has an aged and incipiently decayed appearance.

The local material is mostly somewhat angular, but the foreign material is better rounded. Some pebbles undoubtedly show river action, but more convey impressions of the faceting characteristic of glaciation. An otherwise angular hornblende schist fragment a foot in length has been worn smooth and flat on one side and there are the faintest traces of striation.

The unique character of this deposit is generally recognized by the people who refer to it as a "glacier wash." Prospectors say that it contains a little fine gold uniformly distributed through it, and not concentrated into a basal stratum as in an old river channel. The bed-rock surface is somewhat uneven, but is decayed and, besides, not well exposed. Following the deposit toward the east the bed-rock surface on which it rests very quickly gets to 50 feet above the ditch, and the serpentine-bearing débris ranges to over 100 feet higher. This is quite unlike the habit of an old channel remnant.

There is a 12-inch serpentine bowlder and some rounded cobbles, associated with red dirt, along the old Spooner ditch above the mouth of the Little South Fork Creek. About one-fourth of a mile farther up stream there is a 12×18-inch serpentine bowlder in a draw on a very rocky and steep slope just below the old Spooner flume and probably 200 feet above the river. There are no other erratics and this has evidently slidden from higher on the hill-side.

From the mouth of the Little South Fork Creek to a little point just below the Deep Bank mine, the new course of the river approximately coincides with the old, and all the old channel gravels and local alluvium have been swept from the canyon. The canyon is very narrow and extremely rocky, there being at places, particularly on the south side, perpendicular rock bluffs 75 to 100 feet high. Probably the new canyon has been cut down from 50 to 75 feet below the floor of Channel C, but in addition there have been considerable slices of rock taken off from the

walls of the old canyon, so that the steep rocky walls of a modern appearance rise to 200 and 300 feet above the river. This canyon is so narrow, crooked, and rough-walled, and there are so many projecting narrow rock points, that it is unreasonable to suppose that it has ever been glaciated. If the serpentine-bearing horizon which occurs above this canyon is truly referable to glacial action, the valley has been cut down into very resistant hornblende schist to a depth of at least 200 feet and probably nearly 300 feet since the glaciation. Channel C is far below and very much newer than these supposed old glacial deposits.

The School-house Flat, opposite the mouth of the Little South Fork Creek, probably 500 or 600 feet above the river, has dimensions about 400 × 500 feet, seems to be composed of broken hornblende schist, shows slight landslide topography, no gravel and is very steep on the side toward the river, so that it resembles an old river terrace remnant. A considerable area for some distance west of this flat shows typical landslide topography. Farther up the valley there is another terrace-like landslide deposit, occurring probably 600 feet above the river and occupied by Lakeview, a small ranch.

At the lower end of the Deep Bank deposit the bottom of Channel C is 45 feet above the river. Just across the river on a small point there is a fragment of the same channel and below it a newer channel (Channel D) with its rock floor 15 feet above the river. The outer edge of the Deep Bank is about 200 feet above the river and the inner edge about 250 feet. Just west of the Deep Bank, resting on a steep slope at about the level of the inner edge of the Deep Bank, there is a large granite bowlder (Channel A). The face of the Deep Bank displays stratified, coarse, subangular dark brown (reddish in layers) Crosby Creek alluvium about 100 feet thick. In the channel deposit there are many granite bowlders, rotten but with a hard core. The rock cutting of the new canyon is from 100 to 150 feet in depth, the latter on the south side.

The first south point above the Deep Bank has a marked rock bench at 15 feet above the river (Channel D, occurring in the new canyon) and back of it a remnant of Channel C. Immediately

opposite is the lower end of the most important remnant of this old channel, that opened as Cooper's mine, discussed in the paper before cited. It is preserved for several hundred yards, the river occupying a rock canyon on the south of it. At the lower end the deep narrow channel has its floor about 40 feet above the river. On the borders of the deep channel are flattish, water-worn rock benches which probably represent Channel B. Thin remnants of the ordinary river deposit occur in the bottom of the deep channel. The pebbles are well rounded and the granite bowlders comparatively small. Over this occurs 40 to 50 feet of a stratified deposit partly of subangular local débris, but abounding in granite bowlders, many of large size. This is not the regular river deposit, thins rapidly down stream, becomes very bulky from here up, and I consider it the combined Crosby Creek alluvium and the overwash gravel and bowlders of a glacier which terminated over a mile up the river. Over it is the stratified angular local débris of the Crosby Creek torrent fan, extending to the brow of the hill, nearly 300 feet above the river. Granite bowlders derived from up the river are sparingly scattered through it.

A ditch in the slope of the mountain just above the inner edge of this alluvial fan, exposes a small area (possibly twenty yards in diameter) of rotten granite bowlders and local débris embedded in a sandy clay. It seems to pass down under the edge of the torrent fan and is certainly older. It seems to represent Channel A, having the proper height (350 feet above the river), the aged appearance and the apparent glacial characteristics. On the same line west, but in Crosby Gulch, a large rotten granite boulder is buried under the stratified alluvium of the Crosby Creek fan.

NEAR AND IN THE GLACIAL AREA PROPER.

At the upper end of Cooper's mine a depression crossing a rock point seems to represent the deep channel naturally mined off by the river. Its floor is 45 feet above the stream. Directly opposite the present river but in line with the old channel below, the bowlder bed which is so characteristic in Cooper's mine passes into the bank, has been mined somewhat and the rock

floor shown to be a stream channel. But this rock floor is 100 feet above the river. The old channel may have descended very rapidly at this point, although it is more likely that it is one of the higher channel surfaces in Cooper's mine that is represented, and that the deep channel passed up through the gorge.

The channel on the south of the gorge is preserved for about 500 feet, and is covered by a mass of angular local débris whose surface forms a sloping terrace with outer edge several hundred feet above the river. From where this channel issues from the bank, for fully half a mile up the river, the old and new courses are coincident. But the level of the old channel floor is marked by a change from the precipitous canyon wall to a gentler and less rockier slope above, with an occasional granite bowlder at this level.

On the north side of the river, about one-fourth mile from the lower end of Cooper's flume, there is a cutting through a narrow point, on which occurs a remnant of gravel about 30×100 feet in extent and 5 to 20 feet deep. It rests on a rock slope of about 45° and ranges from the level of the flume, about 300 feet above the river, to 75 feet higher. The bed-rock surface under the gravel is broken and decayed and somewhat irregular. It does not seem to be in the form of a distinct channel. The material abounds in large granite bowlders which are thoroughly rotten to the core, even one 6×8 feet. The remainder of the rock fragments are mainly angular and subangular hornblende schist up to bowlder size. Aside from the granite bowlders, very little of the material is rounded. It is embedded in a sandy clay, inclined to a reddish color. There are no apparent lines of stratification. It looks more like a glacial than a stream deposit. It is very old and rotten and a mere remnant of a once more extensive formation. The lowest portion is over 150 feet above the floor of Cooper's channel, the surface of which, as already described, forms a terrace on the opposite side of the river. This gravel contains an 8-inch and a 2-foot serpentine bowlder, and represents the serpentine-bearing horizon, down the river.

Higher on the same slope, by the "Cape Horn" trail, about

600 feet above the river, there are the huge fragments of a single granite bowlder which had dimensions about 15 × 20 × 30 feet, about 700 tons in weight. There is no gravel with them. They rest on the sloping surface of the hornblende schist and apparently were higher but have slipped down. The configuration of the country is not now, and never has been, such that this bowlder of Courtney granite could have rolled down from its original position on the high mountain to the south. Further, Salmon river never was large enough to have transported this huge bowlder by any process speedy enough to have avoided wearing it out. Bowlders nearly as large are now lying in the bed of the river, but I have recently discovered that they rode into the valley on the backs of glaciers, and the river has not been able to move any of them far down stream. This bowlder apparently reached about its present position by glacial action, and I am compelled to refer it to the supposed glaciation represented by the "Channel A deposits." A flat-lying remnant of them occurs 30 feet above Cooper's flume at "Cape Horn."

At the upper end of the gorge (at the head of Cooper's flume, one and one-eighth miles up stream from Cooper's mine) we have the floor of Cooper's channel (Channel C) well marked as a bench on the south of the canyon, lying 75 to 100 feet above the river. It is encumbered with huge granite bowlders, not much decayed. Turning down stream from the head of the flume, the channel bench occurs on a point overlooking the deep, narrow canyon. Immediately back of it and advancing a point completely across it to the edge of the canyon, there is a pile of rock débris rising in a steep slope to over 100 feet above the old channel and then going back several hundred feet with a gently rising but undulating surface. It abounds in large granite bowlders, some of which occur on its surface. The flattened, plateau-like surface sends a narrow ridge northwestward to the edge of the canyon. On its southwest side there is a gently descending, broad, shallow, rounded depression, clearly not the result of erosion, but such a depression as commonly is found outside of glacial moraines. Back of this depression there is a long, smooth, gentle slope (without granite bowlders) gradually chang-

ing into the steep slope of the mountain above. The bowldery ridge is a glacial moraine. Its steep inner slope is largely due to erosion by the river. It obstructed the old channel and caused the erosion of the canyon.

The surface of the bowlder deposit rises toward the southeast at the rate of 10 to 20 feet in 100 feet, and soon attains a height of over 500 feet above the river. It has, at first sight, the appearance of a typical lateral moraine, with steep inward (ice-ward) slope, then a flat surface 30 to 150 feet wide and then the smooth slope of the unglaciated mountain. This moraine leads to the mouth of a deep gulch (Brown's Gulch) which comes down steeply from the mountain on the south and enters the river valley not far above the head of Cooper's flume. A glacier headed in a basin in the granite at the head of the gulch, extended down the steep, narrow gulch and out into the valley of the Salmon River. This may be called the Brown's Gulch glacier.

The moraine surface at the mouth of the mountain gulch is about 200 feet above the creek. The gulch is so sharply V-shaped as to indicate considerable postglacial erosion. From here up the bowlders on the west are simply scattered over the slope of the mountain, bed-rock appearing frequently, and in many places there is little to indicate a glaciated gulch.

The corresponding "lateral" moraine on the east side attains prominence farther up the gulch and quite likely extends without a break to the glacial basin at the head. The appearance is that this supposed lateral moraine really represents the floor of the glacier and that of the stream has cut a V-shaped gulch 150 to 200 feet deep and partly in hard rock, since the disappearance of the ice. This is an amount of erosion that I am not accustomed to for the time since the maximum extent of the Wisconsin glaciers.

Following the east moraine down, I find it finally separating from the general mountain slope as a broad, transversely flat-topped, independent ridge. This gradually diverges from the west moraine, showing that the glacier, upon entering the main valley, spread out like a fan.

The ridge ends abruptly on the edge of the main valley at a height perhaps 300 feet above the river. A small ditch passes around the point not far below the brow of the hill and its bank exposes the glacial débris. Proceeding east along the ditch, one comes to a fresh ravine leading down the steep slope from the ditch. It exposes 100 feet in thickness of horizontally-stratified, fine, subangular, brown gravel and reddish-brown silt, like in the high bank above Conzetti's mine, discussed in the paper before cited; but here containing a number of granite bowlders, all rotten even when 3 feet in diameter. It is evident that this glacier dammed the valley and formed a pond 300 feet deep, in which the fine gravel and silt accumulated, but right here along the edge of the moraine, granite erratics slid from the glacier into the pond.

Two hundred feet farther east along the ditch we seem to be completely beyond the limit of the glaciation as the bank thence for a long distance shows only residuary débris.

Remnants of the terminal moraine occur on the north side of the valley, opposite the ends of the lateral moraines and connecting these two points, a distance of about 500 feet. Scattered bowlders reach a height of several hundred feet, but hardly high enough to explain the damming of the valley above and formation of the stratified gravel and silt by the moraines alone. Apparently the silt and gravel reached their upper levels by actual ice-damming.

Returning now, to the head of Cooper's flume, we will take up Cooper's channel, here marked by a rock bench 70 feet above the river, and trace it up stream. By reason of the high grade of the present river, the old channel reaches the stream level about 400 feet up stream, and the present rock canyon ends at that point. From here up the valley is comparatively broad, is encumbered by huge bowlders (the residua of the eroded glacial deposits) and no bed-rock shows in the south bank for some distance. From here up the old channel is buried under the present river-bed and passes out of the discussion.

The connection of Channel C with the maximum extension of the Brown's Gulch glacier seems sufficiently definite. This gla-

cier built its moraines directly across the old channel, compelling the river to adopt a more northerly course and erode a new canyon. The overwash gravel and bowlders from the glacier were distributed down Channel C to a point below Cooper's mine. Before this was completed a cloud-burst in the basin of Crosby Creek, formed the torrent fan which is so certainly traceable down the main valley nearly to Summerville. The building of local débris fans over Channel C was an especially characteristic feature everywhere and we are now able to connect it with the glacial stage represented by the maximum extension of the Brown's Gulch glacier. I accept this as evidence of an abnormally moist climate and heavy precipitation in the territory outside of that involved by glaciation.

We will now transfer our attention to the vicinity of the upper falls of the Salmon River, in the gorge which marks the original head of the *old* Salmon valley. Above the gorge, the flat floor of hornblende schist extends out into the broad valley 100 yards as exposed by the river. Since the last or Wisconsin glaciation, the river has carved in this rock platform a canyon 30 to 50 feet deep, and 30 to 50 feet wide at the bottom, with steep, in places, precipitous slopes Through the upward rise of this rock platform and the high grade of the stream, the canyon has become probably 75 feet deep at the upper end of the gorge. A sort of terrace is traceable from the edge of the glaciated platform down through the gorge, particularly on the south side. Next to the river there is a precipitous rock slope capped by granite bowlders. Back of this there is a comparatively gentle slope, encumbered by huge granite bowlders. Above this there is a very steep, rugged slope, apparently unglaciated. The summit of the ridge is rounded, smoothed and covered with erratics. The Salmon River glacier in the last stage clearly overrode this ridge, and seemingly spanned across the gorge to the ridge on the north, whose summit it rounded and covered with glacial débris. The slopes within the gorge are apparently unglaciated (so far as the last stage is concerned) as ragged rock surfaces abound. But the bottom of the gorge at that time was a U-shaped valley descending as rapidly as the present river; certainly it was not such a narrow, rocky

canyon as the present bottom of the gorge. Possibly a small glacial tongue extended down this valley at times, but the bowlders on the south terrace are so numerous and are piled up above the soil in a way to indicate that they were carried over the crest of the ridge on the south and rolled down to the bottom of the valley. Since this event, Salmon River has cut a rock gorge under the older valley, 50 to 75 feet deep. *It descends several hundred feet in less than a quarter of a mile.*

This canyon I attribute to late Wisconsin and post-Winconsin stream erosion. It is rather larger than I am accustomed to for the product of that time, but the flat platform above the gorge, in which this canyon is partly excavated, certainly was glaciated during the last or Wisconsin stage. This canyon is proportionally somewhat smaller than that eroded since the abandonment of Channel C down the river, but at first thought there does not seem to be any very great contrast between them. However, on the ground, the impression is very quickly made on the observer's mind that this upper canyon is much newer than that down the river which succeeded Channel C. Conditions for erosion are exceptionally favorable because it is very high grade. The river descends through it in a series of falls, with perpendicular drops at two places of over 20 feet. The rock is not exceptionally resistant. If this same river had flowed through this gorge since the abandonment of Channel C, it could not have failed to have cut back to the center of the broad valley above instead of only cutting a notch in the edge of the broad, inward-sloping valley rock-floor.

Tongues of ice from the main Salmon River glacier undoubtedly overrode the col during the earlier glacier stages, but during the interglacial or minimum stages, Salmon River did not flow through the gorge, as otherwise it would have completely destroyed the very high grade character of this short section of its course. The broad valley above the gorge was drained by Coffee Creek until late in the Wisconsin or last glacial stage as is evidenced by a broad valley eroded in the earlier glacial deposits just outside of the terminal moraine of the Salmon River glacier in its last stage. This terminal moraine is trenched by an insig-

nificant notch, too small for such a stream as Salmon River to have flowed through it for a single week. When the glacier front fell back a mile, it formed another moraine which dammed the broad valley and turned the drainage of the upper valley through the gorge into the *old* Salmon valley. Therefore, I place the inception of cutting of the canyon in the gorge at a time very little later than the maximum extension of the glaciers of the Wisconsin stage and consider this canyon not more than one-third as old as that eroded since the maximum extension of the Brown's Gulch glacier.

Following the bowlder slope on the south side of the gorge down the valley, its edge gradually gets higher above the river. The bowlder strip becomes pretty steep, then rather suddenly changes to a flat terrace, 150 feet above the river, and whose surface has granite erratics about as numerous as on the floors of most glaciated valleys. This apparently represents the floor of a glacier and we have passed beyond the bowlders which have rolled down from the mountain. The steep slope facing the river is due to stream erosion. Half way to the river is a remnant of another flat terrace, also encumbered with bowlders.

Very shortly the glacial terrace gives out and we come to a slightly higher and steeper slope which has no granite bowlders and seems to be composed superficially of local débris. This is bounded on the river-ward side by a steep bluff 200 or more feet high. On this slope occur granite bowlders. The phenomena indicate a glacial deposit upon which has been built up an alluvial cone of local débris. The river flows in a rather broad canyon trenched below this level.

This slope has an angle of about 15°. Its width from the upper to the lower edge is about 400 yards. Following it down the valley we find built on it a bowldery terminal moraine of the Cohnrad Gulch glacier, which came down from a *cirque* on the northern face of Mt. Courtney. Between this moraine and the river the long slope descends to within 100 feet of the stream, acquires granite bowlders, then becomes undulating and very bowldery, and forms a distinct moraine which appears on both sides of the river and has been cut through by a gorge probably

50 feet deep. Thence extending a quarter of a mile down stream, we find a strong moraine development, great piles of huge granite bowlders rising from along the river to the foot of the steep mountains, a quarter mile back from the stream. This was evidently the work of the Cohnrad Gulch glacier, which barely reached the north side of the valley and scarcely dammed the river. It is a strand of this moraine system that rests on the between 100 and 150 feet of stratified fine gravel and silt above the Conzetti mine, as discussed in the paper before cited. From the way the same moraine system comes down near the river one-fourth of a mile farther up, there was apparently much erosion between the deposition of the gravel and the glaciation of its surface. This is a different conclusion than I have heretofore expressed, as I maintained, in the paper referred to above, that there was no dissection of the fine gravel deposit before the formation of the overlying glacial moraine, but it now appears that that statement was too hastily made. It now appears that a deep, comparatively broad canyon was excavated by the river into this gravel deposit, and subsequently when the Cohnrad Gulch glacier reached the edge of this canyon it tumbled much of its moraine material into it. The maximum extension of this glacier certainly occurred later than the maximum extension of the neighboring Brown's Gulch glacier, and there is evidence of such a long interval between them as constrains me to refer the former to the Wisconsin or last great stage of glaciation. This conclusion is supported by Cariboo Creek having excavated in this glacial débris a much smaller trench than Brown's Creek eroded in solid rock since the maximum extension of the Brown's gulch glacier. Why these two neighboring glaciers should have see-sawed in this manner is not clear, but from a neighboring mountain I have seen that they headed in adjoining *cirques* which seem to have been fed jointly by a higher *cirque*, and a careful examination of the locality may furnish a satisfactory explanation.

Under the stratified gravel and silt just mentioned there is a thin layer of fine gravelly blue clay, which rests on a bed of coarse bowlders and ordinary river gravel. The blue gravelly clay is very strongly contrasted with both the underlying and

overlying deposits. A little farther west it is exposed along the bank for several hundred feet and has a thickness of 6 to 8 feet, with the bottom not seen. It is partially indurated so as to resist erosion well. It is without any apparent stratification and its general appearance is that typical of the ground moraine of a glacier. The included pebbles are partly subangular and partly well rounded. There are faint traces of striation. No serpentine is present, consequently the deposit must be referred to an early stage of the Cohnrad Gulch glacier, a stage apparently closely preceding the maximum extension of the Brown's Gulch glacier and certainly long preceding the stage which formed the moraine *over* the stratified fine gravel and silt.

We will return our attention again to the vicinity of the gorge at the head of the *old* Salmon valley. At Cooper's saw-mill, which is just below the gorge, there is the first of a series of remnants of a terrace which extends down the valley, with a level at first about 50 feet above the river, but gradually decreasing to 30 feet. It is, at the saw-mill, a rock bench covered with gravel and bowlders. The canyon trenched below it is comparable with that developed in the rock platform above the gorge, and I consider this level to represent the closing stages of glaciation in the broad valley above the gorge. The rock bench rapidly descends below the river level and thence the terrace remnants appear to be built entirely, displaying nothing but gravel and bowlders in the bank. This deposit partially filled a rather wide trench excavated by the river into the earlier glacial deposits and the lake deposit of fine gravel and sand. In the vicinity of Conzetti's mine there are several flat-topped remnants of this terrace which lie 30 feet above the river and which formed part of the valley floor at a time long succeeding the Brown's Gulch maximum glaciation; Conzetti is probably in part working this deposit in his hydraulic mine. Unfortunately, between here and the lower old channel remnants farther down the river, there are no more remnants of this late Wisconsin terrace; but it is safe to say that it is not older than Channel D and not newer than Channel E.

On the northern side of the valley, above the saw-mill just

mentioned and hence just below the gorge, glacial débris is scattered thinly over the slope to the summit of the ridge, fully 700 feet above the river and 250 feet above the Big Flat on the opposite side of the ridge. There are some large granite bowlders, but among the material of lesser size, serpentine is conspicuously abundant. This I suppose to represent the last or Wisconsin glacial stage, the material seemingly having fallen from the ice spanning across the gorge. Serpentine occurs in equal abundance in the Wisconsin drift in the broad valley above the gorge. The serpentine is only proportionally abundant among the finer material. Small bowlders and cobbles well-smoothed represent the subglacial and the lower stratum of the englacial drift. Among the large angular and subangular bowlders which were superglacially carried, serpentine is rare in the Wisconsin drift near the gorge, a fact which must be taken into account in comparing this with the serpentine-bearing apparent drift farther down Salmon River.

Leading down the river for about a mile and a half from the saw-mill, the north side of the valley has a more or less continuous strip of glacial moraine material which shows a tendency to form an imperfect terrace at a level between 100 and 200 feet above the river, with a few scattered erratics higher on the mountain slope. This terrace corresponds to that which we have traced on the opposite side of the river. The depression between seems to be a valley of erosion, several hundred feet wide and containing the lower terrace which I have referred to the last glacial stage. If this interpretation be correct, a longer time of erosion separated the two glacial maxima stages than has succeeded the close of the last.

The glacial material forming the indistinct upper terrace on the north of the valley, contains an occasional serpentine bowlder, proving that it was formed by a glacier coming from beyond the gorge, but so far I have failed to find within it serpentine in nearly the abundance in which it occurs on the higher slope just west of the gorge and in the supposed old glacial deposit along the Spooner ditch. I am constrained to consider it as representing neither the earliest nor the latest glacial stage

yet recognized here, but an intermediate stage, probably equivalent to the maximum extension of the Brown's Gulch glacier.

GENERAL CONCLUSIONS.

The preceding detailed descriptions seem to have pretty definitely developed the following:

1. That there was apparently a very old glaciation which connects chronologically with the highest series of river terraces developed in the Pleistocene valleys between Summerville and the coast.

2. That there was an intermediate stage of glaciation which connects definitely with one of the intermediate terraces down the river.

3. That there was a last great glacial stage which connects indefinitely with the lowest series of river terraces, including the "flat valley floor" of the basins between Summerville and the coast.

The relation between the glacial deposits and the river terraces is of extreme importance because a knowledge of it enables us to roughly determine the relative ages of the different glacial stages by erosion studies in a region without the glaciated area and where conditions were more uniform. In this manner I derive the following ideas:

1. That the intermediate glacial stage (always referring to the maximum extension of the ice in each glacial stage) was about three times as long ago as the last glacial stage.

2. That the earliest apparent glacial stage occurred at least ten times and perhaps twenty-five times as long ago as the last stage.

Now, in personally inspecting the various drift sheets in the Mississippi basin and in comparing my observations with those of others, I have acquired the idea that the Iowan drift is from three to five times as old as the Wisconsin, the Illinoian ten or fifteen times as old as the Wisconsin, and the Kansan at least fifty times as old as the Wisconsin. Hence, there naturally follow, as final conclusions:

1. That the deposits of the last great glacial stage in the Klamath mountains fully represent the Wisconsin glaciation.

2. That the intermediate glacial stage probably corresponds to the Iowan.

3. That the deposits supposed to represent the earliest glacial stage yet recognized are *at least* as old as the Illinoian and perhaps as old as the Kansan glaciation.

CLIMATIC CONDITIONS DURING THE SEVERAL GLACIAL STAGES.

The comparative abundance of serpentine in the earliest supposed drift of the Salmon River valley and its rarity as superglacial material in later drifts raises a question as to the cause of this difference. A given glacier in each stage occupied the same valley and would be expected to yield drift of like constitution.

Linked with this phenomenon there is another. I know that the earlier glaciers ran farther than the later, and I have acquired the idea that they were of a radically different character, particularly that they were much thinner at a given distance from the end than were the glaciers of the last stage. This may be wholly imaginary, but I usually do not acquire such ideas without there being some basis for them; in the field I have now studied the earlier drift in three distinct areas (the Union Creek, Coffee Creek, and Salmon River valleys) and each independently has made a similar impression on me. This is after eliminating all differences due to the profound erosion of the earlier drift.

The only satisfactory explanation of the phenomena that has come to light is that as between the earlier and later glacial stages there was a radical difference in the *character* of the climate. *The earlier drift was formed under low altitude conditions and the later drift under high altitude conditions.*

On a recent trip from the coast at Eureka to this region, made shortly after a severe snow-storm, I had the opportunity of observing some meteorological phenomena having a direct bearing on the question at issue. On Redwood Mountain near the coast I found at an altitude of 3,600 feet, a depth of six feet of snow. As I advanced inland, the line of, say, two feet depth of snow gradually rose, and when I reached the region under discussion, I found that there had been not more than two and a

half feet of snow at an altitude of 4,300 feet. A yet greater difference was observed in the melting of the snow. Near the coast the atmosphere was uniformly cold and dense, the sun's direct rays had comparatively little power, and there was no very great difference in the rate of melting of the snow on opposite sides of the valleys. Farther inland and at a higher altitude, the atmosphere was clearer and lighter, weakly absorbent of the sun's rays and radiation rapid. The result was a great contrast in the rate of melting of the snow on opposite sides of east-west valleys. It is well known that it is the great characteristic of an alpine climate that the general temperature of the air is low, but that the sun's rays by direct impact on the earth are very powerful. There is, therefore, a great contrast between the heat in light and shadow, a contrast which is much less at lower altitudes. At this camp, the southern side of the valley will be covered with snow down to the river level, while the sunny slope will be completely bare to an altitude 2,500 feet higher. A northerly facing gulch will be impassable from snow a month after flowers have been in full bloom in a southerly facing gulch at the same altitude.

In my first paper on the ancient glaciers of this region I called attention to the fact that in the last stage (the only one there discussed) they were apparently very sensitive to light and shadow, in their retreat creeping up close to precipitous peaks. It has long been evident to me that the Salmon River glacier in its last great stage was much higher on the west than on the east side, because its chief gathering ground was in the shadow of a high spur of Mt. Courtney, where there is even now a small glacier. Blocks of granite fell from the saw-like crest of the mountain and traveled across the surface of the glacier so as to be distributed along the east slope of the valley. Under these conditions serpentine from the east side of the valley could not very well superglacially reach the gorge on the west side and be carried down the *old* Salmon River valley.

Under low altitude conditions, this glacier would not have been so sensitive to sunlight and one side would not have greatly predominated over the other. Indeed, it is probable that in

that case the longest feeders would have come from the heart of the serpentine area on the east and the conditions for the distribution of the serpentine would have been at least equally as favorable as for the granite. The serpentine-bearing drift appears to me to be more nearly normal than the other. It is fair to acknowledge that the earliest glaciation undoubtedly incorporated in its drift preglacial river deposits in which serpentine occurred in proportion to its outcrop area but this does not fully explain the contrast. It was the peculiar or abnormal character of the later glaciers which caused granite erratics to be present in the drift in a proportion entirely in excess of the outcrop area that caused the difference.

Further, the more uniform temperature of a low altitude climate would enable the early glaciers to run farther down the valleys even though thinner at a given distance from the end than the later glaciers and perhaps containing no more ice. Earlier glaciation was less vigorous than later glaciation. Probably the climate was colder at a given altitude than during the last glacial stage and the ice was sluggish. There seems to have been less tendency for the formation of large moraines than later.

At about the time of the last glacial stage, the country was uplifted and brought under high altitude conditions. The glaciers formed rapidly in the shadow of the peaks, but when they ran out into the open, into strong sunlight, they were soon pinched off by melting.

The character of the climate during the last glacial stage was similar to the present, except for a general lower temperature. Therefore, the altitude may have been at least as high as the present. The character of the climate during an early glacial stage seems to have been similar to that which now belongs to a lower altitude than the present, except for a general lower temperature. These mountains might have been, in an early glacial stage, 3,000 feet lower than at present, but not more, as a depression to that amount would nearly submerge the Summerville basin. Glaciation occurring at such an altitude would, judging from observations made near the coast, yield products similar to the earlier drift discussed in this paper.

In studying the river terraces between the coast and the Summerville basin, I independently arrived at the conclusion that the region of glaciation rose at least 2,000 feet and perhaps nearly 3,000 feet relative to the coast line, at approximately the time of the last great glacial stage and that this region is now as high as it has been at any time during the Quaternary era. Thus two distinct lines of argument are mutually corroborative and virtually establish, to my satisfaction, the fact of such an uplift. It is practically certain that the early glaciation of this region occurred under a lower altitude than the present. Therefore, the theory of elevation as directly and solely the cause of glaciation is inadequate.

I will suggest that there is between the earlier and later drifts in the Mississippi basin a contrast of practically the same character as I have imagined to exist here and perhaps the same explanation may apply. It is well known that there are in connection with the Wisconsin drift sheet evidences of greater elevation during that epoch than during preceding glaciations. During the Kansan, Illinoian and Iowan stages, the altitude may have been low, the climate very cold and comparatively uniform over broad areas, the ice-fields sluggish and the moraines formed, weak. The cause of the glaciation, as many now think, may have been something quite independent of elevation. During the Wisconsin stage, differential elevation may have temporarily resuscitated the ice-fields, but it also brought them under the influence of higher altitude climatic conditions, they were vigorous, but melted rapidly along the borders, ended abruptly and formed massive moraines.

As to the prime cause of the past glaciations, I am as yet far from convinced. At present I am most strongly inclined toward the atmosphere–composition–variation theory as defined by Chamberlin, but some of the ideas advanced in this paper hardly support it. My attention has been called to the fact that what I have described as the great characteristic of the glaciers of this region in their last stage, namely, their sensitiveness to sunlight, may have been produced at a lower altitude than the present, by a decrease in the carbon dioxide in the atmosphere, which is

true. At the same time, the theory seems to imply that to bring about glaciation it was necessary to produce in the atmosphere at the altitude at which glaciation occurred, a depletion in carbon dioxide to considerably less than the present. This would intensify and bring down to a lower altitude than at present what I conceive as the characteristic of a high altitude climate. The earlier glaciation in this region, it would seem to imply, was produced under climatic conditions similar to those which obtained in the region of the later glaciation, although in the former case the altitude was apparently 3,000 feet less. This is contrary to the testimony of the field evidence, if I have read it aright. Perhaps my meaning will be clearer if I state that I conceive that the earlier glaciations occurred in an atmosphere having a larger percentage of carbon dioxide and watery vapor than is now present in the air of this locality.

I expect the reader to accept my argument as to the essential difference of the climate during the earlier and later stages of glaciation of these mountains as suggestions rather than as settled convictions even in my own mind. The study is yet too new and the observations too limited to make the conclusion absolute. My object is to stimulate research along this line in other sections of our western mountains. I see in it a powerful check on speculations as to the cause of the past glaciations.

OSCAR H. HERSHEY.

LAS PERLAS MINE,
May 14, 1903.

VARIATION AND EQUIVALENCE OF THE CHARLESTON SANDSTONE.[1]

THE first detailed geologic work of importance in southern West Virginia was undertaken by Dr. I. C. White[2] in the Kanawha valley in 1884, shortly after the completion of the Second Geological Survey of Pennsylvania.

In transferring his field of activity to southern West Virginia it was natural for Dr. White to look for the same key rocks that he had so successfully used in Pennsylvania, and although the coal-bearing formations increase greatly in thickness toward the south, he identified the sandstone beds showing in the river bluffs at Charleston as the southern representatives of the Mahoning sandstone. Apparently this correlation was based on the lithologic similarity of the two formations, on the division into the same number of members by shale intervals carrying well-marked beds of coal, and on the general succession of rocks upward to the great Pittsburg coal and downward to the heavy beds of the Pottsville sandstone. These correlations of Dr. White were generally accepted, even in detail, by the people of the Kanawha valley, and all of the coal beds were definitely referred to the well-known horizons of the Pennsylvania field.

In beginning areal geologic work in southern West Virginia in 1895, the writer doubtless would have accepted the determinations of Dr. White but for the fact that he was associated with Mr. David White, who was carefully studying the fossil floras of the coal-bearing rocks contemporaneously with the progress of stratigraphic work.

As fossil material accumulated, it became more and more apparent to Mr. White that the correlations then generally accepted were not in agreement with the fossil evidence, and that in the end there would be difficulty in making direct comparisons with the type Pennsylvanian section.

[1] Published by permission of the Director of the U. S. Geological Survey.

[2] *The Virginias*, Vol. VI, p. 716, 1885; also *Bulletin No. 65, U. S. Geological Survey.*

At that time Mr. White's knowledge of the floras of the northern end of the Appalachian bituminous coal basin was based entirely upon published descriptions and a personal familiarity with the Lacoe collection. He had had no opportunity to study the Pennsylvanian floras and their geologic relations in the field and establish for himself a standard section for comparison. But notwithstanding this lack of field experience, the evidence against the identifications previously made was so strong that the writer did not feel justified in accepting the name Mahoning for the sandstone of the Kanawha valley, and proposed in lieu thereof the non-committal term Charleston sandstone.[1]

In proposing the new name the writer was aware that in case the identity of the Charleston and Mahoning sandstones were established the new name would have to give way before the old and well-known term "Mahoning," but on account of the uncertainty he preferred to use the new term and trust to future work to settle the question.

Six years have now elapsed since the name "Charleston" was introduced, and by many the question is still regarded as unsettled, but in that time Mr. White has accumulated such a mass of Paleobotanic evidence against the correlation of these two sandstone formations that there is no longer any doubt except in the minds of those who would discredit entirely the evidence of fossil plants. Although in the opinion of the writer the question is virtually settled, he takes this occasion to present some stratigraphic facts which seem to explain the apparent disagreement between the paleobotanic and stratigraphic evidence.

In order to show the bearing of the facts described in this paper it is necessary to go back and review the evidence that has been presented on the different phases of the question.

In 1900 Mr. David White's study of the fossil floras of the coal-bearing rocks of the Kanawha valley had progressed to such a stage that he published a paper on "Relative Ages of the Kanawha and Allegheny Series as indicated by Fossil Plants,"[2]

[1] CAMPBELL AND MENDENHALL, "Geologic Section along New and Kanawha Rivers, W. Va." *Seventeenth Annual Report*, Part II, pp. 473–511; also *Geologic Atlas of the United States*, folios Nos. 69, 72, and 77.

[2] *Bull. Geol. Soc. Am.*, Vol. XI, pp. 145–78.

in which he stated that the Stockton coal (so-called Upper Freeport bed of the Kanawha valley) carries a flora resembling the Clarion; that the coal bed occurring in the Charleston sandstone in the vicinity of Clendenin on Elk River contains plants belonging to the Kittanning group; that fossils from a higher horizon, but still within the sandstone beds at Clay, are found in the Freeport group of the Allegheny valley, and that the Charleston sandstone is not equivalent to the Mahoning sandstone of Pennsylvania.

These conclusions were not generally accepted. Dr. I. C. White maintained that land plants varied irregularly, and that when they conflict with stratigraphic evidence the latter should be given the preference and the former disregarded. He maintained that the Mahoning sandstone is continuous in outcrop from Pennsylvania to the Kanawha valley, and that consequently his original determinations are correct. In order to be certain of his position Dr. White again took the field and traced the outcrops of the formations in question across the state of West Virginia, and the result was the complete verification, in his own mind, of his former conclusions.[1]

In discussing Mr. David White's paper the present writer called attention to the fact that the Charleston sandstone is a complex formation composed of overlapping lenses of coarse sandstone, and that in tracing it in any direction from the type locality it is doubtful if the original limits can be identified and maintained. He also showed that this variation from point to point might easily explain the apparent continuity of the sandstone outcrop from Pennsylvania to the Kanawha valley, and at the same time allow the diagonal extension of the Allegheny floras across the sandy belt. The conditions which permit such phenomena are shown diagrammatically in the following sketch (Fig. 1) representing an ideal section of the Charleston-Mahoning sandstone from Pennsylvania to the Kanawha valley. The sandstone formation is conceived as being made up of a number of overlapping plates which gradually descend lower and lower in

[1] "Geological Horizon of the Kanawha Black Flint," *Bull. Geol. Soc. Am.*, Vol. XIII, pp. 119–26.

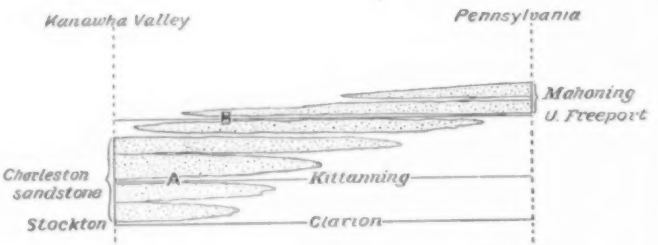

Figure 1.
Diagramatic Section of the
Charleston-Mahoning Sandstone

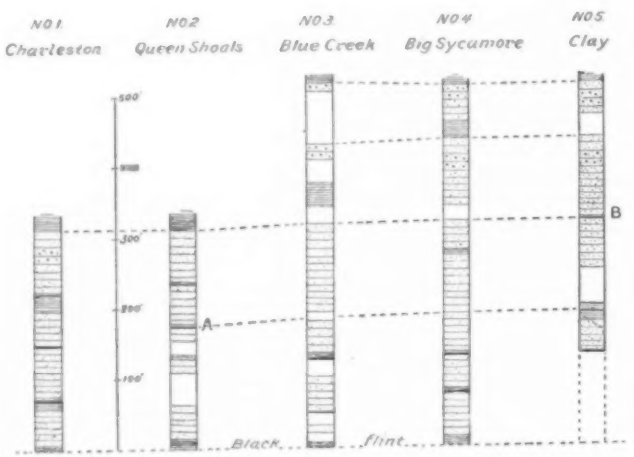

Figure 2
Sections of the Charleston Sandstone.

the series toward the south, until it probably includes the Kittanning horizon, as shown by the fossil flora found in the coal bed (A) at Clendenin twenty miles northeast of Charleston. In support of this proposition the writer called attention to the disappearance of the uppermost bed of sandstone of this group at Sutton, W. Va., and the lowering of the upper limit south of the river by 200 feet, but this being an isolated example, was not given much weight in the discussion of the subject. Recently, however, an excellent example of the variation of these rocks has been brought to the writer's notice and incontestible evidence furnished regarding a marked change in its upper limit between Charleston and Clay. The five sections given in Fig. 2 show something of the nature of this variation, but many intermediate sections might be interpolated so as to make the transition complete.

Throughout the region the base of the formation generally is marked by the presence of a bed of black flint which occurs only a short distance above the Stockton or Lewiston coal bed that has been regarded as the equivalent of the Upper Freeport coal. This is the only bed of flinty character known in the region, and it is easily identified by its débris, which decays so slowly that it is almost always in evidence along the outcrop of the bed. The flint is a local feature covering an ellipsoidal-shaped territory, whose longer axis lies east and west, and extends from Charleston to near Summersville, in Nicholas county. In a north-south direction it is more limited, reaching only a few miles south of Kanawha River in the vicinity of Brownstown and Montgomery, and showing on Elk River in the vicinity of Queen Shoal. Toward the north and west the horizon of the flint passes below water level, but in many places it loses its flinty character before disappearing and becomes a silicious shale which cannot be distinguished from adjacent beds. Throughout the region here discussed, which lies between Charleston and Clay the flint is generally present, and it affords an ideal datum from which to measure.

At Charleston the sandstone overlying the flint has a total thickness of about 320 feet, and its general characteristics are

shown in Fig. 2. It is composed of a number of distinct beds separated by coal and shale intervals, but the sandstone greatly predominates, and the series is essentially sandy from top to bottom. It is well exposed on the south side of the river, and the section was measured on the road which ascends the bluff from the south end of the bridge. The upper limit is marked by a bed of red shale, which is well shown in this region. Above this horizon the material is generally shaly, and the few sandstone beds which appear are generally green, micaceous sands which do not resemble the buff, coarse, sandy beds of the Charleston formation.

The rocks dip gently to the northwest, and the Charleston sandstone is well exposed along Elk River, which follows the strike of the beds to the northeast as far as Sutton in Braxton county. Owing to the crooked course of the river and to the slight undulations which affect the rocks, different parts of the formation are exposed in the river bluffs at different points, but there are only a few places where the base of the series is reached and a complete section exposed. From Clendenin to Queen Shoal the rocks rise steadily eastward up the river, so that a coal bed which is near water level at the former place is by barometer about 170 feet above the river at the latter point. It is from this coal bed that most of the fossils were obtained which Mr. David White[1] has referred provisionally to the Kittanning horizon. Although only a partial section of the Charleston sandstone was obtained at this point, it is introduced to show the position of the coal bed relative to the great mass of sandstone above and below, and to the black flint which is exposed at water level at Queen Shoal. The coal agrees, as stated by Dr. I. C. White,[2] with the North Coalburg horizon of the Kanawha valley.

The base of the Charleston sandstone shows in most of the stream valleys on the south side of Elk River, and the flint is particularly well developed on Blue Creek, which is one of the largest tributaries from this region. The third section, shown in Fig. 2, was measured on this creek six or seven miles above Elk River. Above the black flint occurs a mass of sandy beds

[1] *Op. cit.*, pp. 170–73. [2] *Op. cit.*

having a thickness of over 300 feet. These are broken in a few places by shaly intervals, one of which, about 200 feet from the base, carries a coal of workable thickness. The sandstones are more massive in this locality than in the vicinity of Charleston, and the upper part of the formation is a particularly prominent feature in the topography of the region. In comparing this with the Charleston section, which is regarded as the type, it is clearly seen that the section so far described is almost an exact counterpart, but in the Blue Creek region coarse sandstones are known above the limits just given, which appear to have no equivalents in the Charleston section. The first bed shows a thickness of about 25 feet and it occurs about 100 feet above the top of the regular sandstone section; the other appears to have a thickness of from 10 to 20 feet, and it lies approximately 200 feet above the top of the regular section. The beds of conglomerate are separated by soft shale, in which reds and greens are of common occurrence. In this section it is manifest that the upper conglomerates should not be classed with the Charleston sandstone, since they are separated from it by a distinctly shaly interval.

Along Elk River, from Clendenin to Clay, the Charleston sandstone is well developed, and gives a rough and rugged topography. The fourth section, shown in Fig. 2, was obtained by Mr. Charles Butts near the mouth of Big Sycamore Creek, where the horizon of the flint appears to be near water level. It is true that the flint does not show, and it is possible that its horizon is not exposed, but all the evidence seems to point to the fact that the horizon of the flint is either at or below the grade of the railroad. Although broken by a number of thin, shaly partings, the section consists of a sandy series from near railroad grade to a height of 510 feet. The lower part resembles that found on Blue Creek and also the typical section at Charleston. At a height of 320 feet the rocks are concealed, and it is possible that there is 15 or 20 feet of shale at this point. If such is the fact, it would seem to mark the upper limit of the Charleston sandstone as known at the type locality, but lithologically the section cannot be broken at this point, for the material above is essentially the same as that below. At

a height of 450 feet there is a small shaly interval, which is overlain by 60 or 70 feet of heavy conglomerate.

In comparing sections 3 and 4, it is apparent that the great increase in thickness of the sandy series at the mouth of Big Sycamore Creek is not accomplished by the swelling-out of the Charleston sandstone proper, but by the addition to its upper part of about 200 feet of coarse sandstones and conglomerates, which are feebly represented in the Blue Creek section by thin and independent beds of conglomerate, and are not represented at all in the Charleston section by coarse material. If the three sections given above stood alone, the identity of the beds might be open to question, but in the areal work a score or more of intermediate sections were obtained which make the transition complete and incontestible.

From Big Sycamore Creek to Clay exposures are good along the line of the railroad, and continuous tracing proves that the coal bed which is at railroad level opposite Clay is the same as the coal shown in section No. 4, 125 feet above railroad grade, and occurs only a short distance below the coal bed which is mined between Clendenin and Queen Shoal.

Section No. 5 was obtained on the road which climbs to the upland back of Clay. Although broken by a few small shale intervals the section consists generally of coarse sandstones for a height of about 380 feet above railroad grade. If the section is placed according to the coal horizon, there is a very close agreement with the Big Sycamore section both in total thickness and in the detail of the beds.

Dr. White in discussing the coal outcrops along Elk River[1] correlates the Clendenin coal with a small coal bed 375 feet above Clay, or in other words about the top of section No. 5. It seems probable that this error in correlation is due to the assumption that the observed rise of the beds between Clendenin and Queen Shoal is continued eastward to Clay. In that case it is probable that the Clendenin coal would appear near the top of the sandstone series, but the eastward rise is an assumption which is not in accord with the facts. A broad anticline in

[1] *Op. cit.*, p. 125.

the great northward bend of the river carries the coal high in the hill slopes at Queen Shoal and then allows it to descend to near water level at the mouth of Little Sycamore Creek. The writer is very willing to testify to the general accuracy of Dr. White's work, but he is not willing to have the evidence of fossil plants impeached in the eyes of the public by stratigraphic evidence of this character.

According to fossil plants the Clendenin coal probably belongs to the Kittanning group and the plants collected near Clay[1] from a horizon about 300 feet above the flint are related to the Freeport flora. Although Dr. White calls these two beds the same, a glance at the accompanying sections shows that the stratigraphic evidence is against such a correlation, and that the plant-bearing bed of Clay is distinctly above the Clendenin coal; therefore the latter may be the representative of the Freeport group, if the Clendenin coal belongs to the Kittanning horizon.

A comparison of the sections given in Fig. 2 shows clearly that the observed increase in thickness of the sandy series in the direction of Clay is not due to the great expansion of the formation, but to the addition of coarse conglomeratic members to the top of the original section. These extra members appear first as thin beds of conglomerate in shaly material above the Charleston sandstone proper; they thicken gradually to the east, and finally merge not only with each other, but also with the underlying sandstone formation.

This gives a distinctly sandy series at Clay, which can be traced continuously in outcrop to Charleston, but which manifestly does not represent the same time interval as the Charleston sandstone at the type locality. The uppermost bed at Clay is very much younger than the uppermost bed at Charleston, and if similar changes occur north of Clay, it is possible for the sandstone to be as young as Mahoning on the Pennsylvania line.

The variation in the sandstone between Charleston and Clay appear to be limited to its upper part, but beyond the latter place the writer feels assured that a similar change occurs at

[1] DAVID WHITE, *op. cit.*, pp. 170–73.

the base of the series, except in reverse order as shown in Fig. 1.

If the writer has observed correctly (and the facts seem to be beyond question), it is possible for Dr. White to trace sandstone in outcrop from the well-known Mahoning of Pennsylvania to the Charleston of the Kanawha valley, but that does not necessarily mean that they are of the same age. Dr. White contends that he has traced the coals in a similar manner, but from the great difficulty in tracing coal beds and in identifying their outcrops from place to place, the writer declines to accept this sort of evidence when in conflict with that afforded by the sandstone beds and the fossil plants which accompany them.

MARIUS R. CAMPBELL.

THE PHYLOGENIC STAGE OF THE CAMBRIAN GASTROPODA.

(WITH PLATES I AND II.)

WHETHER it is due to imperfection of the geologic record of the Cambrian age, or whether it is because the class Gastropoda was at that time small and at an initial stage of its differentiation, the species of that age, as known to us, are few, simple-structured, and little diverse, as compared with those of later geologic ages. From the looks of the fossils it might, indeed, be granted that the fauna is both imperfectly represented and primitive. But, as well known, the very simplest and most primitive-looking ones are referable to families the living members of which are believed by zoölogists to be quite remote from the initial or primitive type of the class. If their theory is correct, then the Cambrian Gastropoda must be considered as not near the initial stage of its differentiation, but far advanced, and the Cambrian geologic record as very incomplete. On the other hand, it has not been found explicable why the Cambrian record is so peculiarly and greatly incomplete, and, in short, the primitive looks of the Cambrian Gastropoda are not geologically explained, and the question returns to the interpretation which zoölogists have made of the Recent animal and its shell, whether this is not somewhat at fault for the dilemma. The following paragraphs are intended to offer a concordant interpretation of the geologic and biologic evidence on the Cambrian Gastropoda.

According to the generally accepted view, the gastropod shell, which is the modification of a hollow cone in structure, arose from a symmetrical conical tegulum, and thence the conical, curved conical, spirally coiled, and plane coiled types of shell were successively evolved. The development of the spiral shell has been accompanied by, or has been the cause[1] of, a twisting of the mantle complex of the animal, and since the

[1] See ARNOLD LANG, *Lehrbuch der vergleichenden Anatomie* (Zweite Auflage, 1900), pp. 81–7.

consequent asymmetrical visceral structure is seen in all Recent Gastropoda, including those which now have simple conical shells and the families to which the simplest Cambrian shells are referable, these appear, because of their visceral asymmetry, to have descended in turn from ancestors which had spirals or coils. Some Recent cones are indeed traceable by fossils to coiled ancestors. The larva, too, of many Recent species has a curved or coiled protoconch or larval shell, and this has been taken as evidence or as proof that the gastropods with conical shells had ancestors with spiral shells.[1] Conical shells may therefore be either the ancestral cones or again the last derived stage in their evolution. One is led finally by the evidence of continual series, apparently, of conical shells from Cambrian to Recent time, to the conclusion that, though they seem primitive, the Cambrian shells are not more so than Recent ones—a conclusion, indeed, which it is difficult to accept in view of the very primitive aspect of the whole Cambrian gastropod fauna; and first of all therefore I desire to emend the theory of the relation of the spiral shell to the visceral asymmetry.

ORIGIN OF THE SPIRAL SHELL.

Known Cambrian fossil Gastropoda are referable to Order I, Prosobranchia, excepting provisionally the Hyolithoidea. Regarding the range of the Prosobranchia, Suborder 1, Diotocardia (Aspidobranchia) includes the group Docoglossa, to which belong Scenella and Patella with conical shells, and these together range from Cambrian to Recent time, without known coiled or spiral ancestor. The group Rhipidoglossa includes some Recent conical shells, Fissurella and Fissuridea, which together range from Carboniferous to Recent, and whose only earlier representatives are coiled, such as Bellerophon and Salpingostoma of Upper Cambrian and Ordovician to Triassic. Suborder 2, Monotocardia (Pectinibranchina), has also simple conical-shaped species, the Capulus of Recent time, and Stenotheca and Platyceras which range from the Cambrian upwards. Of these the earlier ones especially have a short coiled apex.

[1] See recently, A. W. GRABAU, *American Naturalist*, Vol. XXXVI (1902), p. 918.

The conical shells of other Gastropoda, *i. e.*, those among Pulmonata and Ophistobranchia, are presumably vestigial from spiral ones, and, moreover, are historically distinct from the Cambrian fauna. The Docoglossa are, therefore, seemingly the only ones without known coiled or spiral-shelled ancestor, and any such ancestor must have existed, if at all, before Cambrian time.

The question is, then, whether the Docoglossa had evolved their shells prior to others through all the stages from the primitive conical through the spiral to the derived conical form, or whether they have had no other than the conical shell as yet. It is not necessary to assume that the Docoglossa had a spiral-shelled ancestor. The aspect of the Cambrian fauna, indeed, suggests that such a theory is not the clue to their evolution. And if it could be proved that the Docoglossa had not a coiled or spiral-shelled ancestor, the dilemma could be removed from the interpretation of Cambrian Gastropoda. It seems at least desirable to avoid the set conclusion that the Docoglossa had spiral-shelled ancestors, and this is practicable only by using a conservative view as to the theory of the visceral twisting and by changing the above-cited theory of the spiral-shelled ancestor.

In support of a new theory, it may further be noted here that the Fissurella type of Rhipidoglossa does not appear early enough in geologic time nor in such association as to indicate the probability of truth in the view of the apical slit of its shell[1] having any homology with the similar structure in Dentalium of the class Scaphopoda. The known early Paleozoic gastropods have not even the marginal slit.

Judging from comparison of the living gastropods, it is obviously not to be assumed that the phylogenic groups or lines in which the spiral shell has longest persisted have the visceral asymmetry most strongly developed; but rather the contrary would seem to be the case. It may even be taken that an asymmetrical long cone, while developing phylogenically, was the sufficient cause for the asymmetrical twist of the viscera as seen now in Gastropoda, and that the short conical shell, on the one

[1] *Op. cit.*, p. 83.

hand, and spiral shell, on the other, mark restored equilibrium. A spiral or complete coil may never have existed in the case of the Docaglossa.

THE TIME SEQUENCE AND FORM SERIES.

If we go back in theory to an ancestral mollusc with solid-layered tegulum, the stages from that to the marginal growth, and consequent hollow enlarged conical shell, seen in the simplest Cambrian mollusc fossils, may be as many as from the latter to the most modified Recent form of it; and the first conical Cambrian shell must well be called gastropod, and considered as far removed from the mollusc common ancestor. How much farther advanced it was may be discussed. Considering that the known Cambrian gastropod shells, in a morphologic sense, may be, some of them, more ancestral or primitive than others, some species or genera should be found among them, as in the later faunas, which were surviving ancient types. Just as the genus Pleurotomaria ranges from Upper Cambrian to Recent time, so also Cambrian genera may have ranged from pre-Cambrian, and the first known fauna may represent an evolutionary series. As said, the long, curved cone is the one which I prefer to consider as the most ancestral type of Cambrian gastropod shell, and the series, on the one hand, to the simple spirals and, on the other, to the short, low conical form, is one-half as long an evolutionary change as from the low conical to the long conical, and to the spiral coil would be. To add, then, from the spiral coil, to the coiled apex, to the secondarily low conical shell, again doubles the length of evolutionary change. In short, the evolutionary series, as represented by the Cambrian fossils, is about one-fourth as long, considering the long curved cone as ancestor of the short cones, as it is if the spiral is taken to precede the derived short cones among Docoglossa.

The time sequence and form series of the Cambrian fossils should indicate the course of development. But that the known Cambrian fauna should not be taken as geologically complete is indicated by the sudden appearance of the first genera. And since the genera known in the Lower pass into the Upper Cam-

brian, where others suddenly appear, it is necessary, in the interest of fairness, to admit that the other Upper Cambrian genera may have existed in earlier time. This admission breaks the force of argument which otherwise would accompany the comparison of Lower and Upper Cambrian faunas, as a developmental sequence. Yet comparison of the Cambrian fauna with the Ordovician Gastropoda, which are numerous as fossils, is competent to decide whether the Upper Cambrian known types are a fair representation of the marine fauna of that time—which, indeed, they appear to be—and this fauna indicates that the Lower Cambrian known fossils are such as should be expected, provided the group is near its initial, from a long curved conical shell, but that also there may have been many other simple-structured species.

IMMIGRATION THEORY.

The Baraboo, Wis., fauna is one which contains several gastropod genera whose geologic and biologic relations are, I think, very characteristically Cambrian, and which are of prime importance. This fauna has been described by R. P. Whitfield,[1] and was referred by him to the Lower Magnesian limestone, an equivalent of the New York Calciferous sandrock. It is from an older formation, as indeed suspected from the first, and is in the Potsdam equivalent. C. P. Berkey has found the fauna at Taylor's Falls, Minn., in the Dresbach formation,[2] in the zone of *Lingulepis pinniformis* Owen, with *Lingula ampla* Owen, *Obolella polita* Hall and *Hyolithes primordialis* Hall. These gastropod species, which were first discovered around the Cambrian Islands of the Baraboo region, as well known, recur at the Cambrian shore region about Taylor's Falls, Minn., in the basal conglomerate, and less frequently in the adjacent brachiopod shales. Any considerable geographic distribution of them in the then seaward direction seems to be disproved because, although the Dresbach formation is soon concealed, it emerges at a greater distance around Trempealeau and La Crosse, Wis., and Dresbach, Minn.;

[1] *Geology of Wisconsin*, Vol. IV., pp. 194–203.

[2] *American Geologist*, Vol. XXI (1898), pp. 270–94.

and there the species of gastropods do not reappear, excepting the *Hyolithes primordialis* Hall. There is, therefore, a good reason for considering the Baraboo gastropod fauna as one occurring only near the Cambrian land, excepting the Hyolithes, which occur also in the normal marine sediments.

This is, I think, the aspect of the known earlier Cambrian molluscan faunas, that Hyolithes and other supposed pteropodous similar genera are common and widely distributed in the marine sediments, and gastropods, Scenella, *et al.*, are rare, local, and probably lived adjacent to land. Their occurrence may, therefore, require an interpretation similar to that which T. C. Chamberlin[1] makes for the fish of the Paleozoic, which he shows to have probably originated in the rivers and later become marine inhabitants, for geologic reasons becoming then abundant fossils. The Gastropoda may be immigrants to the marine habitat in Cambrian time. Assuming that there was a fresh-water molluscan fauna in Cambrian and Ordovician times, and that it is unknown to us, except as it is reflected in the early immigrants and in the preserved land and fresh-water faunas of later ages (Devonian to Recent), then we are able to explain some peculiarities of the Cambrian Gastropoda. From an ancestral gastropod stock in fresh water several immigrations to the sea may have taken place in Cambrian to Ordovician time, and that is what causes the emergence of new genera which we see in the marine fossils.

To illustrate from the region of the upper Mississippi valley, where the encroachment of the Cambrian Sea, as shown by Walcott, was in later Cambrian time, the oldest exposed strata are in the Dicellocephalus zone and of the Potsdam equivalent, and above this follows the Magnesian series, which is the Calciferous sand rock equivalent. Both have a known gastropod fauna; though it is necessary to offer a correction here, since inadvertently lists of fossils, such as that in *North American Geology and Palæontology* by S. A. Miller, refer species of the upper division only to the lower or Potsdam, and those of the "Potsdam" all to the upper division, which is the Calciferous or "Lower Magnesian," excepting *Hyolithes primordialis* Hall, which is rightly

[1] Jour. Geol., Vol. VIII, pp. 400–412.

placed. Correctly referred, the faunas appear as follows: Associated with the brachiopod Lingulepis and the trilobites Agraulus and Dicellocephalus in the Dresbach formation occurs the *Hyolithes primordialis* Hall, widely distributed seaward, while at the seashore, as described, with it are the gastropods Tryblidium (Metoptoma), Hypseloconus, and Scævogyra. The succeeding Franconia sandstone, at Taylor's Falls, Minn., has the same genera of gastropods. This may be taken as the equivalent to the top of the Potsdam of New York.

The next succeeding formation, the St. Lawrence, contains in a trilobite zone at Osceola, Wis., near Taylor's Falls and only a mile or two from the then seashore, *Tryblidium* sp.?, *Pleurotomaria sweeti* Whitf., *Murchisonia putilla* Sar., and *Bellerophon antiquatus* Whitif. At another point on the Blue Earth River, Minnesota, which is near another shore of that time, *Murchisonia putilla* Sar., was found either in the base of the Jordan sandstone, or as I suspect, now really the top of the St. Lawrence formation. Also *Raphistoma minnesotense* Owen and *Ophileta alturensis* Sar., occur in the same matrix. *R. minnesotense* Owen also comes from Red Wing, Minn., which is distant from the shore. Next, the coarse Jordan sandstone is practically the unfossiliferous basal sand of the Oneota dolomite, and this one is the supposed Lower Calciferous sand rock equivalent. Fossils generally have been obliterated in the Oneota, but a few Lingulas, and two fragments of trilobites, have been found, with a number of gastropods, which are the same species as those enumerated from the St. Lawrence formation, with also others of the genera Straparollus, Holopea, and Ophileta. Cephalopods also occur, of the genera Ascoceras, Piloceras, Orthoceras, *et. al.* The superjacent Shakopee dolomite (Upper Calciferous) contains only gastropods and cephalopods, as far as known, and, excepting the genus Subulites, they are species very similar to, though not identical with, those of the Oneota,[1]

In all these localities and horizons where the gastropods occur there are evidences of shallow water to be found, con-

[1] F. W. SARDESON, "The Fauna of the Magnesian Series," *Bulletin of the Minnesota Academy of Natural Science*, Vol. IV (1896), pp. 92–105.

glomerate, breccia, oölite, or mud balls. Rounded pebbles one or two inches in diameter occur even in the St. Lawrence formation of Red Wing, Minn. The species of fossils are quite all different from those of eastern America. Also the St. Peter sandstone (Chazy) has its peculiar molluscan species, but following this formation the Galena (Trenton) has numerous species which are largely identical with those from other regions, and surely of normal marine habitat.

Thus in this region one appears to see the Gastropoda crawling off the rocks of the Cambrian seashore, migrating seaward, and becoming in Ordovician time the companions everywhere of the Brachiopoda and Trilobita, and this has suggested to me the probability of non-marine origin of Mollusca.

Such a theory does not change in any way the estimated imperfection of the geologic record as to the Gastropoda, except that the meaning of the same is differently taken when the ancestral stock is assumed to be the fresh-water fauna and not the salt-water one. The fresh-water and land faunas are totally unknown, and our Cambrian gastropods are immigrants, and thence the marine ancestors of Prosobranchia. The later emerging groups of Pulmonata and Ophistobranchia, for example, are not necessarily descended from the known Eo-Paleozoic, but would be descended from that unknown common stock. Cephalopoda may be derived from the first immigrated, widely found marine pteropodous genera Hyolithes, Hyolithella, etc. The class Pelecypoda, all but unknown in the Cambrian, might be taken as the third immigration seaward, and Scaphopoda the fourth. In this connection, I recall a former occasion for surprise when, in discovering Ordovician fossils in the St. Peter sandstone, I found that the Pelecypoda were both present and predominated, and Gastropoda and Cephalopoda were also in it. That formation is as unfavorable for fossils as any of the Cambrian fossil-bearing zones well could be, and therefore the Pelecypoda seem to have just arrived.

THE EARLIER CAMBRIAN FAUNAS.

A review of the Cambrian representatives in the light of these theories may elucidate somewhat the phylogenic stage, whether

primitive or whether advanced in Cambrian time. Walcott[1] describes about twelve species of gastropods in the Olenellus zone, or Lower Cambrian, and as many of the Hyolithoidea, or supposed pteropods. The Gastropoda include four species of Scenella (Plate I, Fig. 1) which are conical shells, about as high as wide; aperture elliptical or oval, tending to narrow posteriorly when the apex also inclines backward. The species are rather variable as described (*loc. cit.*), and in that respect not unlike the species of the Ordovician.[2] The genus apparently merges into the Patella of Silurian to Recent time, and is therefore of the Cyclobranchia as now known. Stenotheca (Plate II, Fig. 13) includes three species, distinguished from Scenella by concentric wrinkling of shell. A tendency in such shells toward curvature of the apex is worthy of note (*S. curvirostra* S. and F.). Platyceras, two species, includes *P. primaevum* Bill (Plate II, Fig. 14), which has a short, dextrally coiled apex or spire. The apex coils obliquely to the assumed dorsal direction. The aperture has the narrower side next the suture. *Straparollina remota* Bill (Plate II, Fig. 20) is a short dextral coil, with spire depressed and rounded in outline; whorls nearly uniformly rounded, more narrowly so on the upper side near the suture and also on the basal side. *Raphistoma attleboroughense* S. and F. (Plate II, Fig. 25) is a small dextral shell of three spiral whorls. These are rapidly expanding, closely coiled, and rather narrowly rounded on the outer side, which is a little thickened.

Helenia bella Walc. (Plate II, Fig. 17) is long, curved dorsally, and has an elliptical aperture, beveled toward the posterior. The apical end of it is imperfectly known. Similar to this one are the genera supposed to be pteropods. Hyolithes, including eight species, are long, conical, transversely broadened, anteriorly flattened, dorsally more or less angular, and the aperture is extended at the anterior side. There are sometimes apical loculi, and there is an operculum. In some there is a tendency to curve dorsally. Hyolithellus includes one species—a very

[1] U. S. Geological Survey, *Tenth Annual Report*, pp. 616–25.

[2] The variability of Ordovician species of Scenella, Archinacella, etc., has been greatly underestimated by some authors.

long cone, or tubular. Coleoloides, one species, and Salterella, three species, of short tubular shells, complete the list as given by Walcott.

The above species are very small shells, as compared to later ones like those of the Ordovician, and they were the kind to be the less easily and often fossilized because small and thin. There is little doubt that their small size and simple structure are truly representative of the earlier Cambrian marine Gastropoda of the Canadian and New England region.

The Baraboo fauna includes several species in three genera. Tryblidium (*Metoptoma* Whitf.) (Plate I, Figs. 2, 3) includes shells similar to Scenella, but the apex is more excentric and directed toward the narrower end of the oval or acuminate aperture, and the muscle scar is broken into distinct paired spots arranged in a circle or in horseshoe-shape, open anteriorly. In Hypseloconus (Plate I, Fig. 6) the apex rises posteriorly to the center, but by the curvature of the shell is directed forward. The muscle scars are apparently like those in Tryblidium. Scævogyra species (Plate I, Figs. 8, 9) are short, sinistral spiral coils. *Hyolithes primordialis* Hall is the accompanying pteropod. The western Upper Cambrian has therefore a primitive gastropod fauna similar to that of the eastern Lower and Upper Cambrian.

In interpreting these very simple types of gastropod shells there is noticeable difficulty at the start in choosing the right point of view. I have taken the generally oval aperture to be posteriorly acuminate and the apex as directed backward. In Scenella it ranges to anterior in position, but points rather backward because of a concave slope on that side of the shell. In Hypseloconus it rises posteriorly, but points forward. In other cases the curvature or coil may be assumed as backward directly or obliquely. There may have been a reason why the aperture was posteriorly narrowed. The animal is presumed to have been longer than wide, whence an oval shell could be well fitted to it, and, in case the shell rested back of the middle, the anterior of the shell might well be broader than the posterior, to accommodate the body at retraction. The curvature may be backward from some like simple cause. But in larger coils the

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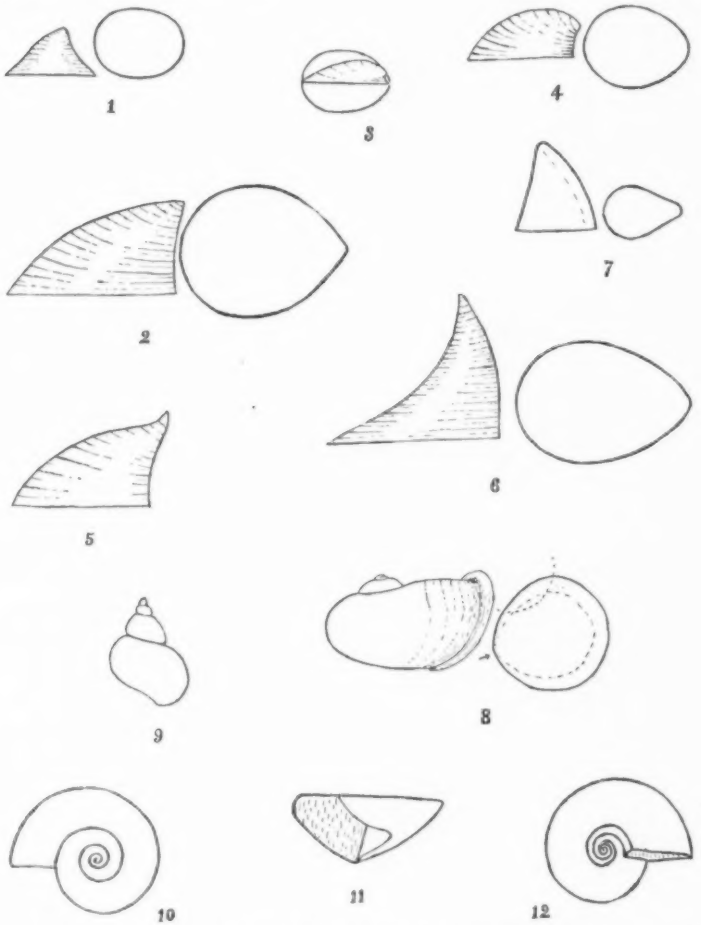

FIG. 1, *Scenella reticulata* Bill., after Walcott; 2, *Tryblidium barabuense*, Whitf., ×½; 3, *Tryblidium simile* Whitf., ×½; 4, *Tryblidium nycteis* Bill., ×½; 5, *Tryblidium retrorsum* Whitf., ×½; 6, *Hypseloconus recurvum* Whitf., ×½; 7, *Metoptoma orithyia* Bill., ×½; 8, *Scævogyra sweezeyi* Whitf., ×½; 9, *Scævogyra elevata* Whitf., ×½; 10, 11, and 12, *Maclurea acuminata* Bill., after Whitfield, ×½.

same cause could not operate well because of change of poise or relation of shell to the body, and the acuminate aperture may not remain evident where the curvature has changed. The curvature may be taken as backward or lateral, and backward not forward, by rule, since the exception in Hypseloconus is seen to be a reversal (*vide H. recurva* Whitf., Plate I, Fig. 5). It is also notable that the Hyolithes curve backward when at all, and a reason for considering the angular side of Hyolithes as the posterior one may be deduced also from the triangular cephalopods. The initial of Endoceras is hyolithoid-shaped and angular dorsally; and, indeed, the frequent angular feature in early Cephalopoda, such as Gonioceras, and Triptoceras suggests that the oval acuminate aperture may have been ancestral. The cephalopod shell may have derived the marine hyolithoid species by formation of lateral loculi, in the manner described by Holm, in place of terminal ones, and the descent may have been in Cambrian time from Gastropoda to Hyolithoidea and to Cephalopoda, whence an ancestral trait of the oval aperture. Further, Cephalopoda and Hyolithoidea have not a coiled embryonic shell. Gastropods in the Cambrian should not, then, have, and are not known to have.

The curvature or coiling in the apex of the early Cambrian Gastropoda appears either equal to or greater than that in the maturer shell (*Platyceras primaevum*, Fig. 14), and correspondingly we may outline the morphologic series from that of the long conical to the apically curved, the apically coiled with curved base, and the entirely coiled, in accordance with the theory advanced, *i. e.*, that the shells of Cambrian time were coiling and not uncoiling. That these belong to an uncoiling stage would be tenable only on the evidence of an unknown fauna of spiral shells as old as, or older than, this one. Of that there is no proof. We do not know that there was a Cambrian larval spiral protoconch. In Recent shells such may have resulted altogether as it has in part since then. And, as said, the twisted mantle complex may have required no further cause than the shifting of a long cone. Taking the theory that the long conical shell, in Cambrian time, was ancestral to both the

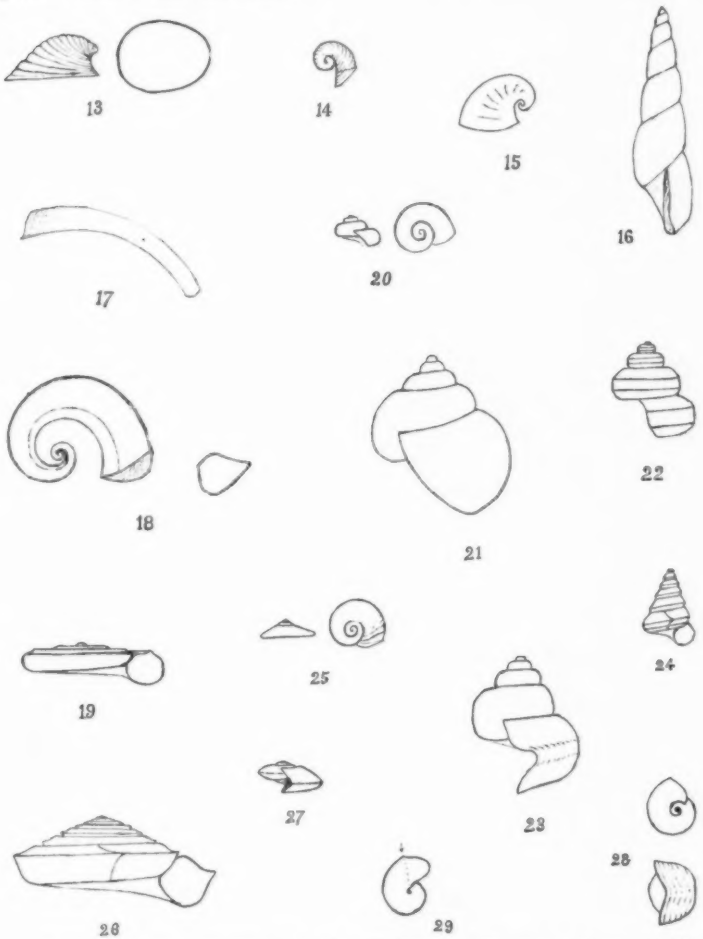

FIG. 13, *Stenotheca rugosa* Hall, after Walcott; 14, *Platyceras primaevum* Bill., restored, after Walcott, ×2; 15, *Platyceras primordiale* Hall, ×½; 16, *Subulites exactus* Sar., ×½; 17, *Helenia bella* Walcott; 18, *Ecculyomphalus triangulus* Whitf., ×½; 19, *Helicotoma similis* Whitf.; 20, *Straparollina remota* Bill.; 21, *Holopea obesa* Whitf., ×½; 22, *Trochonema exile*, Whitf.; 23, *Pleurotomaria sweeti* Whitf.; 24, *Murchisonia putilla* Sar.; 25, *Raphistoma attleboroughense* S. and F., ×4; 26, *Raphistoma minnesotense* Owen, ×½; 27, *Raphistoma leiosomellum* Sar., ×½; 28, *Owenella antiquata* Whitf.; 29, *Bellerophon vel Protwarthia*, ×½.

shorter cones and the spiral coils, the manner in which the spirals arose may be interpreted from the phenomenon seen in the Cambrian Gastropoda, where ontogenically the apex of the shell coiled most; and the conclusion is drawn that phylogenically the apex coiled first and the "body whorl" last. This is contrary to the view which has heretofore been held.

Possibly the example of uncoiling spiral shells in later geologic ages and the embryonic evidence of the Recent larval coiled shell have been applied too hastily to the interpretation of Cambrian Gastropoda. In the Cephalopoda the coiling is better known and affords fine examples for comparison. The correspondence of stages in phylogeny and ontogeny among the Ammonoidea, where the straight, curved, coiled, and uncoiled structure follow in order, is well known. In the Nautiloidea there very early occur both the coiling and the supposed uncoiling; and, indeed, there are such types as Ophidioceras, which is convolute in the middle and uncoiled at both ends. In this case the interpretation of the apical end as progressive and the apertural end as retrogressive might be taken as not sufficiently proved to serve as evidence. The Belemnoidean Recent genus Spirula is seen to have derived from a straight phragmocone, but is apically coiled, *i. e.*, it is in a genetic sense coiling, but appears uncoiling. After all, the Cephalopoda afford indecisive results, even if it was safe to apply a cephalopod measure to the grastropods. If anything fitting this case is indicated by them, it is that even within the group Gastropoda such uncoiling shells as Vermetus do not prove the rule.

The "Studies of Gastropoda"[1] by Grabau has come to hand after the above paragraphs were outlined and it may serve to indicate how firmly the view opposite to that here presented is held generally. Grabau unhesitatingly interprets *Platyceras primaevum* Bill., as a phylogerontic unrolled type.[2] He further cites Ordovician species as phylogerontic, following Ulrich's figures and descriptions in these, where, in the first instance, my collections lead me to conclusions widely different from those of Ulrich. We have to do with highly variable shells of fewer

[1] *American Naturalist*, Vol. XXXVI, pp. 917–45. [2] *Op. cit.*, p. 938.

species than he describes. The "various degrees of uncoiling" are rather within a species in each case. That they are gerontic is, secondly, not assured.

Returning to the early Cambrian shells, the feature, in long cones, of the apical region coiling more than the maturer portion of the shell does is not necessarily to be interpreted as "uncoiling" in a genetic sense, but is as well or better to be considered as due to the curvature having set in at the apical region, and thence affecting the entire shell. Similarly, the reverse curvature is seen to affect the apex of *Tryblidium retrorsum* Whitf. (Fig. 5.), and the entire shell of *Hypscloconus recurva* Whitf. (Fig. 6), the former being then the transition from the normally curved long cones to the recurved short cones of the latter.

In all cases the change from straight to curved and coiled shell is accompanied by a change from directly transverse to obliquely cut back aperture in a very natural manner, as if the curvature of the shell preceded the elongation of the anterior, *i. e.*, the convexed side of the cone.

The next noteworthy feature is that, while the conical shells, which are very variable species, appear in each fauna, the coiled spiral shells are dextral in the eastern Olenellus fauna and sinistral in the Baraboo fauna. In this case the sinistral shells are evidently not sinistral derivatives of dextral ancestors by the depressing of the apex, as once suggested by Billings, below the median plane, since such transitions are unknown. A coiled intermediate type between the Raphistoma and the Scaevogyra does not appear, and coiling in bilateral symmetry was seemingly not yet developed or not yet immigrated. The link from the sinistral to the dextral shells may be interpreted as the known long conical type, and the two kinds of spiral shells as arising by parallelism. The sinistral might also be simply a mysteriously reversed form of the dextral, though they do not appear to be the sinistral individuals, or the near reverse of any dextral form, but relate rather to the retrorse long conical, Hypseloconus.

THE CALCIFEROUS FAUNA.

The next succeeding fauna is in the Calciferous. This group may be considered as descended in main from the earlier types

which are known to us, though a few are probably from unknown ancestors. In this Calciferous fauna there are, first, a number of short obtuse cones, of which *Tryblidium niobe* Bill. and *T. nycteis* Bill. (Fig 4) have the same general aspect as species of of the Baraboo fauna; *i. e.*, the shell smooth, curved with the apex overhanging the narrower end of the ovate aperture. The apex is, therefore, directed posteriorly, as I take it, though authors generally have designated the same as the anterior, because the line of paired scars of the type species were supposed to be open at this end, in a similar way as the continuous scar opens anteriorly in Patella. Ulrich and Scofield find otherwise for Tryblidium, and it may be better compared to Archinacella and Scenella, which have a continuous muscle scar which is not open anteriorly. These two genera occur also in the Calciferous zones. The one is low, smooth, conical, the other somewhat higher and ornamented, the apex being either central, or toward the broader, or toward the narrower end of the oval aperture. They, with Metoptoma (Fig. 7), may readily be taken to be the descendants of earlier species of Tryblidium, Hypseloconus, and Scenella, together comprising all such as have changed to shortened or lower cones, and they may be taken as tending toward the Patella, *et al.*, of more recent ages. Further, an interpretation of them might indicate that the apex is centrally or posteriorly directed, except in the Hypseloconus line, which would be the reverse of that, *e. g.*, *Metoptoma orithyia* Bill. (Fig. 7), and again that the broader end of the aperture is probably anterior.

Next to be mentioned is the genus Platyceras (Plate II, Fig. 15), which continues through and beyond the Calciferous zones, and is still intermediate between Stenotheca and the dextrally spiral shell type. Closest related to it is probably Holopea, but this is not clearly derived from it. Strangely enough, the division line between Diotocardia and Monotocardia, which so narrowly separates Scenella and Stenotheca, would also seem to divide the genus Holopea; or probably the Holopea-like species, when better known, may be found to be distributed between Holopea proper and Straparollus or a similar genus.

The Calciferous species of Holopea (Plate II, Fig. 21), Trochonema (Fig. 22), Straparollus, if the presence of this genus is conceded, and Raphistoma (Fig. 26), including *Raphistomina*, U. & S., are advanced little, except in respect to size, over earlier Cambrian dextral shells. They have the aperture simply formed, *i. e.*, cut obliquely from the sutural side (posterior) to the opposite (anterior) side. Holopea has rounded whorls, slightly impressed, forming a moderate spire with open umbilicus. Trochonema is similar, with angulations of the right or upper side of the aperture, producing keels on the whorls. Straparollus is a longer tube, coiled with wider umbilicus and more nearly discoid than Holopea. Raphistoma is low-coiled, with angulated anterior or periphery.

Other and associated types in the main may be viewed as modifications of these, by change of aperture and spire. In the case of these—to make a theory to fit the phenomena—there is a tendency in many species toward an extension of the apertural margin at the under outer side of the whorl, which produces a sinus, as in *Pleurotomaria* (*Seeleya*) *sweeti* Whitf.[1] (Fig. 23), which otherwise is like Holopea (Fig. 21.) Whether this apertural change is considered to be the building forward of certain parts or the cutting back of another, as writers generally have held of such shells, the species are in later time followed by others in which the change is more developed, the Calciferous species appearing to be midway in an evolutionary change which, in general terms, is a tendency to produce the aperture nearly in the plane of the shell's axis of coiling, *i. e.*, transverse to the volution. At the same time a notch is formed. The sinus in this case arises apparently not in front, but to the right side.

Closely related, though a link nearer to it may be shown, is the *Bellerophon* (*Owenella*) *antiquatus* Whitf. (Fig. 28), which is bilaterally symmetrical, since the spire is drawn in or sunken to the median plane of the volutions, and at the same time the aperture is built out below symmetrically, to form a broad sinus, which probably in this case was shifted to anterior, median of

[1] *Holopea sweeti* Whitf. There can be no doubt that the specimens in hand are Whitfield's species.

the animal. The genus or subgenus Protwarthia (Bellerophon) is also reported from the Calciferous. *P. cassinensis* Whitf. has the shell more rapidly expanding, (*i. e.*, shorter), the aperture larger, and the sinus narrower by reason of its sides projecting or building forward, as in the later *Bellerophon bilobatus* (Fig. 29). On the other hand, Oxydiscus, *e. g.*, *Bellerophon macer* Bill., while likewise bilaterally symmetrical, is convolute with abrupt umbilicus, and the aperture cuts obliquely backward, forming a wide sinus, the middle of which coincides with an angulation which is a keel peripheral to the volution.

A composite of these four genera and a transitional form from *P. sweeti* to the other three would be such as the species which I formerly described, as *Raphistoma leisomellum Sar.*[1] (Fig. 27), which consists of "about four rapidly increasing volutions, which embrace in such a manner as to form a lenticular coil," nearly equally convex above and below. The body whorl overlaps notably the periphery of the spire, though it is not a plain coil, the spire rising a little on the upper side, and an abrupt umbilicus, about one-fourth the width of the shell, being on the lower side. The periphery is narrowly rounded and slightly inflated, and the aperture is like those in Bellerophon and Pleurotomaria of the Calciferous.

Contemporaneous with and related to *P. sweeti* are a number of shells with high spires, in contrast to Bellerophon. They are comprised in the name Murchisonia *auct.*, or again under several generic terms—Lophospira, Clathrospira, Plethospira, Hormotoma, Cœlocaulus, and Tunitoma. These have a sinus, the abrupt middle of which produces a band upon the volutions, often coinciding with a keel (Fig. 24) or one of the keels. None of the species seem to have the sinus narrowed to a slit, as in the case of some of the later genera.

It may be true of these Murchisonia-like shells that the transition from a sinus to a slit has not yet been observed,[2] and this observation is not supplied here. The slit appears geologically later in species which logically seem to be the descendants of

[1] *Bulletin of the Minnesota Academy of Natural Science*, Vol IV (1896), p. 99.

[2] *Quarterly Journal of Geological Society*, Vol. LVIII, p. 317.

those which have the sinus. The view of Ulrich and Schofield, and Koken, that the sinus precedes the slit genetically is rather unavoidable, since apparently in Bellerophon, Pleurotomaria, *et. al.*, in later geologic time a slit appears where in shells of Calciferous age a sinus only occurs. There is, however, formed in species of Calciferous age a more or less distinct band by the more or less distinctly truncated bottom of the sinus. The building out of the apertural margin so as to narrow the sinus is in process of formation, though a "slit" would not be formed until the sinus is narrowed to the width of the band. The slit differs from the sinus in that growth-lines coincide upon its sides, as they were tending to do in the sinus, and a slit appears to have arisen from the sinus in several distinct genera, by parallelism of development. Further, the theory may be extended to the effect that the sinus, as seen in Protwarthia, Seeleya, Lophospira, *et al.*, is best explicable as the result of a genetically parallel development, their common ancestor having then had only its incipient stage developed. In the genera next to be mentioned here the presence of a sinus is not taken as evidence that the ancestor common to them and the preceding genera had other than a simple oblique shell aperture.

The low coiled shells, Helicotoma and Ophileta, have, therefore, been well united[1] with Straparollus in the family Enomphalidæ. The Straparollus has, of course, the obliquely cut aperture which I consider primitive. The other genera have the outer lip produced, making a sinus which as a rule coincides with a keel on the outer upper side of the whorls; and a band, when present, runs upon the keel. A slit has not been perfected in any of them. Helicotoma (Fig. 19) has the apex of the spire rather above the level of the elevated keel on the upper side. Ophileta has it rather lower, and the shell is less rapidly expanding than in Helicotoma. Another genus similar to these, Ecculyomphalus (Fig. 18), is coiled in one or more free volutions in nearly one plane. Authors generally have considered it an uncoiled shell, though it is better to regard it as coiling, showing a comparatively less rapidly developing retarda-

[1] Ulrich and Schofield, *Geological Survey of Minnesota*, Vol. III, p. 1023.

tion rather than retrogression. The existence of a well-developed sinus in view of parallelism of development does not argue that the shells are uncoiling. For the probable Lower Cambrian ancestral type of Ecculyomphalus, one may as well or better choose Helena (Fig. 17), a long curved cone, rather than the coiled Straparollina, since it is nearer the former in stage of coiling and equally far from both as to the aperture.

The genera which are referable to Montocardia in the Calciferous are Platyceras (Fig. 15) again and probably Holopea (Fig. 21) proper, the latter a symmetrical, short, spiral coil with primitive oblique aperture, reminding one of Straparollina, but much larger. With these, some species of high spiral shells, referred to the genus Subulites (Fig. 16) or somewhat uncertainly to Fusispira, emerge in the Calciferous. Like Holopea, they have no ornamentation, but a high, closely coiled spire, shallow sutures, and an elongated aperture. Between the straightness of the outer side and the impress of the preceding volution the sutural or posterior end of the aperture is narrowly acuminate. The apertural margin diverges from the simple obliquely backward course, or primitive aperture, by arching forward of this direction from the suture across the periphery, and then backward near the anterior end, and forward equally to the columella, making a neat sinus or canal at the anterior end.

It is unnecessary to more than mention the probable ancestral position of these Subulites shells in relation to the geologically later siphonate forms of the Monotocardia. The form of aperture in Subulites follows the tendency, herein suggested, to build forward from the obliquely and backward to the axially parallel direction, the difference from Pleurotomaria shells being in the position of the remaining notch, sinus, or canal, which is near the columellar instead of the peripheral margin.

In that way one can compare the Calciferous coiled shells with supposed primitive dextrally coiled Lower Cambrian ones with simple aperture, excepting in case of Maclurea (Plate I, Figs. 10, 11, 12), which is more difficult. If it is viewed as a dextral coil (Fig. 12), the spire, as Billings suggested, has sunk far below the median plane, in short, the umbilicus is then plane,

the spire is reversed, and the aperture is then equally changed from the primitive obliquely backward position to somewhat obliquely forward. On the other hand, if it is viewed as a sinistral shell (Fig. 10) related to Scævogyra, the aperture runs then somewhat obliquely backward, and the narrower or posterior side of the aperture is at the umbilical margin (Fig. 11), as in that genus, to which the coil also corresponds, being more or less completely convolute (*vide M. speciosa* Bill.), though the spire's height is rather uniform. From what is known to me of Scævogyra, its species are considered to be rather greatly variable ones, and those of Maclurea, including Maclurina, are also not entirely constant. Even the great number of taxonomic species given by Ulrich (*op. cit.*) from the Galena is reduced to one species when a large number of specimens are examined. Comparison of immature specimens of Maclurea with Scævogyra will, I think, argue a close relationship between the two genera.

It is probable that Maclurea descended from Scævogyra, and that these are nearest to Hypseloconus and Tryblidium. Scævogyra does not occur after the Cambrian time, and, regarding later descendants of Maclurea, none are known, unless they become dextral shells. The mooted transitional forms or linking species between Ophileta and Maclurea in the Calciferous, if ever demonstrable, may be turned to argue the conversion of a primitive sinistral type to dextral Enomphaladæ, instead of inversely. The Enomphalidæ are, indeed, an ambiguous group, but whether, by reason of diverse origin of species, included in the family or not, does not yet appear.

Whether the Baraboo gastropods and Maclurea became extinct by dying out, or whether they have converged in part into other taxonomic groups, does not appear. They may be related to Recent Gastropoda in the manner of an offshoot from the ancestral fresh-water ancestors, and may be wholly extinct.

THE ORDOVICIAN GASTROPODA.

The Ordovician gastropods next succeeding the Calciferous present an increased diversity, which is obviously an advance or

continuation of the supposed development through Cambrian time It is unnecessary here to interpret it all in detail. Suffice it to note that in genera like Salpingostoma there is a maturity stage which was a new feature then in gastropod shells.

It will be useful to determine for the Ordovician species how much less constant they are in their characters than later gastropod faunas. There is danger of exaggeration, no doubt, if experience gained from a study of later Gastropoda is applied *a priori* to these earlier ones, since these may have the shell in a highly plastic stage, and seemingly great differences may not have a high taxonomic value. Such seems to me to be the case in studying large, carefully made collections, and accordingly I am inclined to desire a simplification of the taxonomic plan. In case of Pleurotomaria, both it and Bellerophon may have arisen from Raphistoma species, which argues close linking between these three. Again, Pleurotomaria may be from Raphistoma in part and from Holopea-like species in part; but this argues not only that the dividing up of Pleurotomaria, somewhat as Ulrich and Scofield have done, is logical, if practicable, but also that Raphistoma and Holopea-like species and their consequents are not genetically far apart. In case of Ordovician gastropod species, very excellent specimens are to be had in large numbers, at least in the upper Mississippi valley region, and these, when carefully studied, appear to show a high degree of variability. Ulrich and Scofield (*op. cit.*) have repeatedly based many taxonomic species on a few rather highly variable ones. The Ordovician fauna confirms the Cambrian shells to be rightly considered as little diverse, but variable to a high degree as compared with Mesozoic and recent probable descendants from them.

CONCLUSION.

The early Cambrian Gastropoda are taken to be in an initial stage of differentiation, the amount of their evolutionary development at that time being represented by the change from a long curved conical to a short conical, on the one hand, and to short spiral coils on the other. The asymmetrical long conical shell is taken as the most primitive form among Cambrian Gas-

tropoda, and the one from which the short conical shells, on the one hand, and the spiral and coiled shells on the other, have descended. Conical shells have arisen also from coiled and spiral ones in later geologic ages. The visceral twist probably correlates with the development of the long asymmetrical cone, or most primitive form, and not with the spiral shell.

The ancestor of the Mollusca was probably living in fresh water, and there the ancestral gastropods began. The Cambrian Gastropoda which are known to us appear to be immigrants to the sea, the fresh water and land stock remaining unknown to us geologically, though they may be reflected in the known marine immigrants. The Hyolithoidea may represent the first migration seaward. They comprise long conical, more or less curved, often triangular shells, and are the normal marine species, very probably representing the class Pteropoda; and from the same the Cephalopoda may have derived.

The second migration comprised the other Lower Cambrian Gastropoda. They are taken to be the ancestral group of Prosobranchia, and to be in process of change from long curved conical to short conical, on the one hand, and, on the other, to spirally coiled. The coiling is at the shell apex first and strongest; *i. e.*, the coiled form of mature shell arises by retardation. The aperture is simple and is oblique to the radius of the curve, or, in other words, the shell is not longest on the convex anterior side, for which reason the aperture runs obliquely backward from the inner (posterior) to the outer (anterior) side of the volution.

The gastropods in the Calciferous formations are readily interpreted as derived from the Lower Cambrian species, with certain exceptions. These are short conical shells, the Docoglossa. The Rhipidoglossa comprise species of long coils, with more or less changed aperture, which arises essentially by the building forward of the anterior or convex side of the shell, leaving near it a sinus in the margin, *e. g.*, Bellerophon, Pleurotomaria, and Murchisonia. These forms undoubtedly belong to Suborder 1, Diotocardia. To Suborder 2, Monotocardia, belong similarly Platyceras and Subulites, in the latter of which the aperture forms a shallow anterior canal.

The third immigration is that represented by the Baraboo fauna, with curved conical shells, retrorse shells, and sinistrally spiral ones. In the Calciferous there are the shorter cones, Tryblidium, and the sinistral spiral Maclurea. This group is somewhat problematical, being doubtfully Prosobranch and possibly Ophistobranch, recognizable species of Order II, Ophistobranchia, appearing first in the Devonian and Carboniferous, in the genus Actæonina. Order III, Pulmonata, at the same time appears in the genus Archæozonites and Dendropupa. Those three genera are primitive-looking, but of no recognized exact relation to any contemporaneous or preceding ones of the Prosobranchia among fossils; and it may be considered that their ancestors of Cambrian time were in the fresh-water fauna, from which also the Prosobranchia separated by migrating seaward in Cambrian time. The practically sudden emergence of marine Pelecypoda in the Ordovician time finally permits a theory of their freshwater origin, at that time, in accord with the view that Mollusca as a whole began in fresh water habitat.

FREDERICK W. SARDESON.

MINNEAPOLIS, MINN.
May 30, 1903.

NODULAR-BEARING SCHISTS NEAR PEARL, COLORADO.[1]

THE central area of the Pearl district consists of schistose rocks which are cut by numerous dikes of coarse pegmatite, varying from two to forty feet in width, and having a general northwesterly and southeasterly strike. Numerous copper prospects are being developed upon these, and in several instances bodies of copper ore have been discovered. Associated also are veins of quartz, which are of great interest because of the fine crystals of spinel, of the variety ceylonite, which they contain. Octahedra of from 5 to 25^{mm} in diameter are found in large quantity. That which makes them especially interesting is the fact that all the crystals contain quartz inclusions in the greatest abundance, often to such an extent as considerably to lower their specific gravity. The spinel occurs in portions of the dikes which are almost wholly quartz. The included quartz appears to be identical with that surrounding the spinel. It would seem, therefore, that part of the quartz had crystallized out before the formation of the spinel, and the remainder followed the crystallization of the spinel. In other words, we have two generations of quartz crystals, the first generation being partly included in the spinel.

To the southwest of this lies another area of schistose rocks which are cut by dark basic dikes. These dikes are mineralized, and upon them prospects are also being opened up. They are an example of what the average miner firmly believes to be always the case—increase of value in depth. At the surface they show little sign of mineralization, but upon sinking chalcopyrite appears in considerable quantity, and seems to have been original with the dike matter, as the dike is perfectly fresh and shows no sign of mineralizing action. If the chalcopyrite was

[1] The recently opened mining town of Pearl is situated in Larimer county, Colo., about two miles south of the state line between Colorado and Wyoming, and at an elevation of about 8,400 feet (barometric).

original with the dike matter, why it appears in depth and not at the surface is a question that I am not prepared to answer.

Between these areas is a band of biotite schist which presents an unusually fine example of the stringing out and plication of quartz lenses. At times a single lens will have been squeezed to a band scarcely an inch thick and folded on itself from a dozen to twenty times, the folds being several inches to several

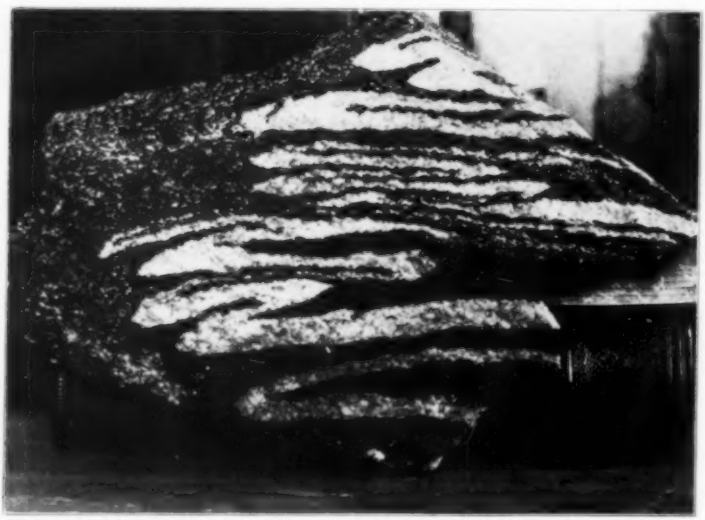

FIG. 1.—Plication of quartz vein in schist.

feet long and sometimes only a fraction of an inch across. The white quartz against the dark background of the schist presents a most striking appearance. This is shown by the accompanying photograph (Fig. 1). The size of the specimen can be judged from the volume of the *Neues Jahrbuch* which is used to prop it up. In a width of about six inches we have twelve folds, so that the same band appears twenty-four times. It seems most probable that in this case the quartz must have existed as a vein in the rock before its metamorphism, and the oscillations which took place during the metamorphic processes have produced

this interesting effect. It is to be noticed that, in general, the thicker portions are on the same phase of the fold.

The occurrence of the greatest interest lies in the second area mentioned above. This is a belt of schist about one hundred feet wide, full of ellipsoidal nodules which vary in length from one to four inches along the greatest axis. As they are harder than the schist, they weather out in relief, and immediately suggest to the beholder the "prune granite" of Quincy, Mass., excepting that the "prunes" are in this case lighter in color than

FIG. 2.—Iolite schist, showing projecting nodules.

the rock mass. The accompanying photograph of specimens of the rock will afford an idea of their appearance (Fig. 2).

Upon microscopic examination these nodules prove of unusual interest, because they largely consist of, or have been derived from, a mineral which has had very little notice in North American petrography, namely, iolite. Except as an accessory in certain basic rocks in Minnesota and as a mineralogical occurrence in various localities in the East, it has scarcely been mentioned. Abroad, however, it has frequently been described.[1]

Only surface material was available for study, and in this the iolite, as is usually the case, is much altered, the common altera-

[1] *Vide Zeit. fur Kryst.*, Vol. XXIX, p. 305; also Vol. XXXI, p. 248; *Neues Jahrbuch*, Vol. XI (1899), p. 84; *Bull. de la Soc. de Sc. Boucarest, Roumanie*, Vol. III.

tion products of pinite and other secondary minerals having replaced it to a considerable extent. In most cases, however, what Dana describes as the first stage in the alteration of iolite has taken place—namely, the division of the iolite prisms into plates parallel to the base, and the development of a pearly luster on the plates. This pearly luster is especially prominent, and at first glance would deceive one into believing that the mineral is muscovite. The hardness and brittleness of the plates quickly dispel that illusion, however. It is interesting to note that, usually, a nodule displays this luster equally all over its surface at the same angle of illumination, showing that the crystallographic axes coincide throughout the mass, as though it were originally a single crystal.

In the hand specimen the nodule appears practically homogeneous, but in thin section, in addition to the iolite and alteration products, grains of quartz appear. How much quartz is present cannot be readily determined, for where the interference figures cannot be obtained quartz and iolite are indistinguishable, except by microchemical tests. I do not think the amount is large, however. The iolite shows its characteristic pleochroic halos, and often contains inclusions whose nature could not be determined.

The ground-mass of the schist is ordinary muscovite-biotite schist, the two micas being about equal in amount. It seems extremely probable that the muscovite has resulted from the alteration of grains of iolite scattered throughout the rock mass, as it is slightly more brittle than the ordinary muscovite.

The origin of the iolite, and, more especially, the origin of the nodules, is a question that could not be answered without further study of the region and also of the rock.

Three miles northeast of Pearl, in Wyoming, and apparently diametrically across the pegmatite area from the iolite schist, is another interesting belt containing veins of argentiferous lead and zinc ores. It is a schist resembling in a general way that in which the iolite occurs, and it, too, is full of nodules. These are irregularly prismatic in shape, differing from the iolite nodules in that respect. Further, they consist entirely of quartz

which is full of rutile needles to an unusual extent. The needles seem to be arranged in approximately parallel positions, and are so numerous that they create false lines of cleavage in the quartz, it cleaving readily in one direction and with more difficulty at approximately right angles to this. The sagenitic structure common to rutile needles when they occur in quartz in large amount does not appear to be anywhere present.

The occurrence of the two schists in such proximity, and both containing nodular segregations, would lead one to suspect that there must be some connection between them. Speculation upon it with present data is useless, however. After further study features of great geologic interest may be discovered.

In concluding I wish to thank Dr. W. C. Knight for the notes and specimens put by him at the disposal of the writer.

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Reviews

SUMMARY OF THE LITERATURE OF NORTH AMERICAN PLEISTOCENE GEOLOGY 1901 AND 1902. II.

FRANK LEVERETT.

CENTRAL AND EASTERN CANADA.

BELL, ROBERT. *Report of an Exploration on the Northern Side of Hudson Strait.* Geol. Survey Canada, Ann. Report, Vol. XI, Part M, 38 pp., 1901.

Baffin Land, which forms the northern side of Hudson Strait, was until 1875 supposed to consist of a group of islands, but now it appears to be one great island with an area of about 300,000 square miles. There are, however, numerous small islands along the south coast. Three prominent mountain ranges trend north-northwest to south-southeast parallel with the eastern coast, the highest of which borders that coast. The high interior north of Cumberland Sound is reported by Boas to be ice-capped like Greenland. Around the margins of the ice-cap the general elevation is about 5,000 feet, and it reaches about 8,000 feet in the central part. Another area of smaller extent, but apparently equally high, lies a short distance farther northwest. The mountainous region between Cumberland Sound and Frobisher Bay stands apparently between 2,000 and 3,000 feet. The tract between Hudson Strait and Frobisher Bay is largely covered by the Grinnell glacier, which is 70 to 100 miles in length and about 20 miles in breadth. It was reported (but not verified) that one narrow tongue of ice extends down to the water of the strait. The mountains are apparently interspersed with lakes, two of which are of great size, Lake Netelling being 60 by 140 miles, and Lake Amadjuak at least 40 by 120 miles. Their greatest diameter runs parallel with the mountain ranges north-northwest to south-southeast.

Hudson Strait, as pointed out in 1895[1] was probably occupied by a river that drained the Hudson Bay basin at a time of high altitude when the basin was dry land. Soundings show the strait to have a channel 200 to 300 fathoms in depth. The ice-sheets of the glacial period moved down from the high land on both sides, and then down the valley itself, as shown by the striation and the materials of the drift.

On the part of Baffin Land examined, bowlders are a conspicuous feature, and a sandy or gravelly till is abundant. Osars were noted southwest of Amadjuak Lake. The general glaciation seems likely to have been rather remote, for the surface of the drift is much oxidized, and the limestone surfaces show considerable decay. Striæ are conspicuous only at low levels along the coast. A table containing observations of twenty-two striæ is given. Giant potholes 8 to 20 feet in diameter were noted on the border of the entrance to Canon Inlet.

The sea has stood at various levels, above the present, long enough to form well-defined beaches. Beaches were noted at several points at elevations of 360 to 400 feet, as well as at various lower altitudes. On a mountain side west of Akuling Inlet

[1] In a paper by DR. BELL in the *Scottish Geographical Magazine.*

beaches and terraces were found at 378 and 528 feet. Drinkwater reports observing a beach about 600 feet above the sea on the hills above O'Brien Harbor at Cape Chidley. Shells of *Saxicava rugosa* and *Mya truncata* were found imbedded in till on one of the Islands of God's Mercie at 200 feet, and the Saxicava shells in drift at lakes Gertrude and Greely at 110 feet.

CHALMERS, ROBERT. *Notes upon the Pleistocene Marine Shore Lines and Land Slips of the North Side of the St. Lawrence Valley.* Geol. Survey Canada, Vol. XI, Part J, Appendix I, pp. 63–70, 1901.

The marine plain or bottom land of the St. Lawrence valley extends from 8 to 30 miles north of the river in the district between Quebec and Montreal. The river bank is usually but 15 to 25 feet, but in passing back toward the northern limits, along the base of the Laurentian hills, there is a rise to 400 or 500 feet. The slope is terraced, apparently by marine shore action. The shore lines are found to increase in height from east to west, the rate of rise of the highest one between Quebec and Lachute being about two feet per mile.

The landslips here reported have occurred at various dates from 1840 to 1898, and lie below the level of the highest shore line. The most recent one, May 7, 1898, filled the Rivière Blanche valley 25 feet for a distance of nearly two miles. The cause of the landslips is stated by the author to be due to (1) the silty and arenaceous character of the Leda clay, rendering it capable of absorbing and retaining a large amount of water, and (2) the increased precipitation during the season these landslips occurred, which saturated the deposit and gave them greater weight than usual.

CHALMERS, ROBERT. *Surface Geology of Part of Ontario.* Geol. Survey Canada, Summary Rept. for 1901, pp. 158–68.

In company with R. W. Ells, the western limit of marine beds was traced northward from Brockville to Smiths Falls. Clay thought to be of fresh-water deposition was noted at Lyn, Gananoque, Kingston, and westward.

Oil wells at Petrolia, Oil Springs, and Sarnia penetrate 100 to 125 feet of surface deposits before striking rock. Rock is reached near Bothwell at 210 feet and at Dutton at 255 feet, while at Tilsonburg it is reached at 74 to 81 feet.

In parts of the Thames valley gas is obtained from sand and gravel below hardpan at a depth of about 90 feet.

The following series of drift beds is reported to occur in western Ontario:

1. Surface clay, sand, or gravel, more or less oxidized.
2. Bowlder clay of irregular thickness, sometimes wanting.
3. Sandy and silty beds, in places forming the upper part of the Saugeen clay (interglacial).
4. Saugeen clay, interglacial, partially oxidized and somewhat sandy in upper part, fresh-water shells in lower part.
5. Erie clay, interglacial, color bluish-gray, sometimes darker, stratification more or less distinct; contains fresh-water and land shells (Campeloma, Succinea, Polygyra, etc.), in upper part; localities noted are Pelee Island and shore of Lake Erie.
6. Bowlder clay, usually a thin sheet resting either on the decomposed or the solid surface of the "fundamental rocks."

The so-called interglacial beds Nos. 3 to 5 often have a combined thickness of 100 to 150 feet.

A former level of the Great Lakes lower than the present is shown by the following lines of evidence: (1) by stumps along the Lake Erie shore west of Port Rowan with their roots in soil below lake level; (2) by tree trunks in a layer of clay and marl in the mouth of Maitland River at Goderich 10 to 15 feet below the level of Lake Huron; (3) streams discharging into Lakes Huron, St. Clair, Erie, and Ontario have their lower courses flooded from the lakes. In the case of the Thames and the Sydenham the depth of flooding is 10 to 25 or 30 feet, and extends for several miles up the stream.

Spits and dunes on the north shore of Lake Erie are being built mainly by winds that blow from the southwest, those on the north shore of Lake Ontario by winds blowing from the east.

COLEMAN, A. P. *Marine and Freshwater Beaches of Ontario.* Bull. Geol. Soc. Amer., Vol. XII, pp. 129–46, 1901.

Marine deposits and shell-bearing gravel and sand extend up the St. Lawrence valley to Brockville, both on the Ontario and New York side, but have not been found farther west, though the same body of water is known to have extended into the Ontario basin. Plant remains found in clay nodules in Ottawa are those of a cool-temperate climate like the present climate of that region. The remains of marine animals are of species found now in the Gulf of St. Lawrence.

Higher shore lines are found, and other evidences of static water at high levels, but the author doubts if any of these higher shore lines are postglacial and marine. On the contrary, they appear to have been produced by glacial lakes. In some cases the beaches contain fresh-water fossils.

Attention is called to evidences of northward differential uplift in the Great Lakes region, and it is considered probable that the highest beaches were formed at a comparatively slight altitude above the sea. The objection raised against ice-dams, that no glacial mass could withstand the pressure of a head of water hundreds of feet in depth, may find no application here if the land was relatively low, and is thought to be of doubtful pertinence even under conditions of high altitude.

COLEMAN, A. P. *Sea Beaches of Eastern Ontario.* Rept. of Ontario Bureau of Mines for 1901, pp. 215–27.

Describes the character and distribution of the sea beaches and the faunas which they contain. Also gives a few observations on the Leda clay and the Saxicava sand.

COLEMAN, A. P. *Iron Ranges of the Lower Huronian* [Ontario]. Rept. of Ontario Bureau of Mines for 1901, pp. 181–211.

Although dealing chiefly with the iron-ore bodies, a brief discussion of the Pleistocene geology is presented.

COLEMAN, A. P. *Glacial and Interglacial Beds near Toronto.* Jour. Geol., Vol. IX, pp. 285–310, 1901.

Presents a connected history of events in the Ontario basin from the retreat of the Iowan ice-sheet, which is summed up as follows:

1. Retreat of the Iowan ice-sheet.

2. Interval of erosion, with water probably lower than at present.

3. Don stage, warm-climate trees, and Mississippi unios, water dammed by differential elevation toward the northeast to 60 feet above the present lake.

4. Scarboro peaty clays, cold-temperate climate with trees and mosses, and 70 species of extinct beetles, formed as a delta by Laurentian River in interglacial Scarboro Bay.

5. Scarboro stratified sand with some trees and freshwater shells of cold-temperate climate, delta completed; lake stood 152 feet above the present.

6. Water drawn off by lowering of outlet, subaërial erosion of previous beds, and cutting of river valleys more than 150 feet deep.

7. Advance of Wisconsin ice front raising the water to about 160 feet, as shown by stratified interglacial clay, retreat for 50 miles and readvance, followed by two later retreats and advances, the water finally rising 360 feet above the present lake.

8. Final retreat of ice-sheet followed by water levels of lakes Warren and Iroquois, and a brief entry of the Gulf of St. Lawrence into the Ontario basin, which, however, remained fresh.

The reviewer questions whether the Iowan drift is well represented or even present at this locality, since the interval shown by the interglacial beds appears to be much greater than observations in the region where Iowan and Wisconsin drift sheets are well displayed would lead one to expect. This does not invalidate in any way the conclusions announced in this paper; it simply suggests that the lower till sheet may be Illinoian.

COLEMAN, A. P. *Duration of the Toronto Interglacial Periods.* Am. Geol., Vol. XXIX, pp. 71–79, 1902.

In reply to a paper by Upham which had appeared in the *American Geologist*, Coleman estimates the time required for the processes which took place between the two advances of the ice. Of this time 1,300 years is considered a low estimate for laying down the interglacial beds and 2,500 years for trenching them; it is considered probable that the time should be more than doubled. The warm-climate flora is shown to be inconsistent with the view that the ice-sheet was near by. The author holds it probable that the ice had disappeared as completely from Canada in that interglacial period as at the present time, which perhaps is embraced in another interglacial period.

COLEMAN, A. P. *Relation of Changes of Levels to Interglacial Periods.* Geol. Mag., Dec. 4, Vol. IX, pp. 59–62, 1901.

It is thought there was an uplift to the northeast, followed by a depression. The uplift would render Labrador cooler and help start an ice accumulation, and this in turn would tend to depress the region. The melting of the last ice-sheet would allow the land to rise again. It is a problem whether this elevation to the northeast would be sufficient of itself to cause glaciation.

CURRIE, P. W. *On the Ancient Drainage at Niagara Falls.* Trans. Can. Inst., Vol. VII, pp. 7–14, 6 pls., 1901.

(Not examined.)

DOWLING, D. B. *Physical Geography of Red River Valley.* Ottawa Nat., Vol. XV, pp. 115–20, 1901.

The geological history is sketched, and with it the development of the main physical features. The effect of glaciation and of the occupancy by the Glacial Lake Agassiz form the closing part of the discussion.

DOWLING, D. B. *West Shore and Islands of Lake Winnipeg.* Geol. Survey Canada, Ann. Rept., Vol. XI, Part F, 100 pp., 1901. Published as a separate in 1899.

Superficial deposits are discussed on pp. 93–100, and include till, drumlins, reassorted bowlder clay, stratified sands and gravels, and lake beaches. The bearings of striæ are also given, and a map of part of Lake Winnepeg shows striæ and drumlins.

DOWLING, D. B. *East Shore of Lake Winnipeg and Adjacent Parts of Manitoba and Keewatin.* Geol. Survey Canada, Ann. Rept., Vol. XI, Part G, 98 pp. 1901. Published as a separate in 1899.

This report is edited from notes by J. B. Tyrrell. While dealing mainly with the hard-rock geology, there are brief references at various points to glacial deposits, lacustrine deposits, striæ, potholes, etc. The eastern limit of lacustrine deposits is noted (p. 43).

DOWLING, D. B. *The West Side of James Bay.* Geol. Survey Canada, Summary Rept. for 1901, pp. 107–15, 1902.

A traverse was made on the west shore of James Bay, and a survey of Equan River. The deltas of Moose and Albany rivers are briefly described. Clays with marine fossils occur up to nearly 400 feet above tide in the vicinity of Sutton Mill Lake.

DOWLING, D. B., and J. B. TYRRELL. (See Tyrrell.)

ELLS, R. W. *Three Rivers Map Sheet of Quebec.* Geol. Survey Canada, Ann. Rept., Vol. XI, Part J, pp. 63, 1901. (Published as a separate in 1900.)

The occurrence of marine shells in sand or gravel above clay is apparently restricted to the vicinity of the St. Lawrence River, none having been noted on the high areas to the north. Striæ are rather rare because of the limited outcrop of Paleozoic rocks and because weathered quickly from the gneiss. The general bearing is north-south.

ELLS, R. W. *Ancient Channels of the Ottawa River.* Ottawa Nat., Vol. XV, pp. 17–30, with map, 1901.

The paper opens with a reference to the Ottawa as one of the great historic waterways, Champlain having ascended it in 1615, and crossed the portage at Lake Nipissing, "presumably the first white man to gaze upon the vast expanse of our inland seas," while afterward the river became the chosen route of the voyageurs inland to the great unexplored country, and the principal channel for the business of the Hudson Bay Company. The geologic history of the river is made to begin far back of the Glacial epoch, though it is recognized that marked changes were produced by glaciation. Borings show that part of the lower course has a rock floor below the sea level, and the depth of Lake Temiscaming (470 feet) brings its bottom to within 121 feet of sea level. The valley is thought to have experienced several cycles of uplift and depression. The author inclines to the view that a postglacial marine submergence covered lands between the Ottawa and Hudson Bay now standing over 1,000 feet above sea level.

The paper deals mainly with the departures of the present stream from a deep

preglacial channel, the course of which was determined by borings, and is represented on a map for a distance of about 200 miles, from Roche Capataine, in longitude 78° nearly to Montreal.

ELLS, R. W. *The District around Kingston, Ontario.* Geol. Survey Canada, Summary Rept. for 1901, pp. 170–83.

Notes briefly marine deposits at Brockville, the probable Iroquois shore line near Tamworth, and the occurrence of shell marl in many lakes in the area north of Kingston.

ELLS, R. W. *Marl Deposits of Eastern Canada.* Ottawa Nat., Vol. XVI, pp. 59–69, 1902.

Discusses deposits in Ontario, Quebec, New Brunswick, and Nova Scotia, and refers the deposition of marl to the action of air upon spring water containing bicarbonate of lime.

FLETCHER, HUGH. *Kings and Hants Counties, Nova Scotia.* Geol. Survey Canada, Summary Rept. for 1901, pp. 208–14.

Refers briefly (p. 211) to drift material, striæ, old beaches, and shell marl.

JOHNSTON, J. F. E. *Eastern Part of the Abitibi Region.* Geol. Survey, Canada, Summary Rept. for 1901, pp. 128–41.

Describes briefly the streams, lakes, peat, timber, soils, fish and game, as well as the hard-rock geology.

LAFLAMME, J. C. K. *Geological Exploration of Anticosti.* Geol. Survey Canada, Summary Rept. for 1901, pp. 188–94.

The stream valleys are largely excavated in gravel and calcareous detritus of modern origin, and postglacial clays are also present. A few striæ bearing northeast-southwest were found at Rivière Du Cap. The highest parts of the island carry glacial bowlders. The island was apparently covered by the Champlain sea. The uplift following the submergence is distinctly marked, and the two phases of it are shown by systems of terraces. The present shore seems to be undergoing uplift, for parts of its beach are not reached by high tide. Marl lakes are common on the island. Soils are variable.

LOW, A. P. *Exploration of the South Shore of Hudson Strait.* Geol. Surv. Canada, Ann. Rept. Vol. XI, Part L, 47 pp., 1901. (Published as a separate in 1899.)

The glacial geology is discussed on pp. 34–47. Although the highest hills are glaciated, there is little drift material except bowlders above 400 feet A. T. The ice movement was radial toward the coast. The highest marine terrace noted is 405 feet. Reference is made to a marine limit of 700 feet at Richmond Gulf in Hudson Bay, of 300 feet at the south part of Ungava Bay, and of 325 feet at the mouth of Payne River.

LOW, A. P. *Report on the Exploration on the East Coast of Hudson Bay.* Geol. Surv. Canada, Ann. Rept., Vol. XIII, Part D, 86 pp, with 2 maps, 1902.

Describes the physical features of the coast and presents a few notes concerning the northern interior. The northern limit of forests, the climate, and

the fisheries are briefly treated. Near Cape Wolstenholme patches of perpetual snow were discovered. Three sets of striæ were noted in the Labrador peninsula, which are interpreted to indicate a transference of the center of glaciation northward, it being at an early time between the 50th and 51st parallels near the center of the peninsula, at a later time north of the 54th parallel, and still later between the 55th and 56th parallels and only about 100 miles inland from the east coast of Hudson Bay.

South of Hudson Bay two sets of striæ were noted, the older set running from northwest to southeast, thought to be the product of the Keewatin ice-field, and a later set from north-northeast to south-southwest, referable to the Labrador ice-field. A long list of striæ observed east and south of Hudson Bay is presented.

Subsidence of land accompanied, and perhaps continued subsequent to, the ice accumulation, and this was followed by an uplift which has carried the old marine shores to a maximum height of nearly 700 feet above the present sea-level. The limits, however, appear to be much lower in the northern part of the peninsula. (See preceding paper.)

McEvoy, James. *Report on the Geology and Natural Resources of the Country Traversed by the Yellow Head Pass Route from Edmonton to Tête Jaune Cache.* Geol. Surv. Canada, Ann. Rept., Vol. XI., Part D, 44, pp., 1901. (Published as a separate in 1900.)

The route described leads from the plains east of the Rocky Mountains westward over the front range of mountains. The physiography and the general character and extent of the several formations including the Pleistocene are briefly discussed. Glaciers were noted in the Selwyn Range on mountains 8,000 to 9,000 feet in height, and west from there on mountains that reach 11,000 feet. The drift deposits are heavy near Lake St. Anne, with bowlders of Laurentian granite and fossiliferous Devonian limestone brought from the north and northeast. The limits of eastern drift are placed about a mile west of Wolf Creek. Farther west the bowlders are from the Rocky Mountains. A glacier apparently flowed northward down the Athabaska valley. The highest mountains show no striæ, and their sharp angular appearance is thought to indicate that they have not been glaciated. However, a mountain 8,000 feet high, situated eight miles east-southeast from Tête Jaune Cache, was glaciated; the striæ bear south 25° west.

McInnis, William. *Region Southeast of Lac Seul.* Geol. Surv. Canada, Summary Rept. for 1901, pp. 87–93, 1902.

Contains brief notes on the fall of streams, the river terraces, the outline and depth of lakes, and the features of the drift.

Parks, W. A. *The Country East of Nipigon Lake and River.* Geol. Surv. Canada, Summary Rept. for 1901, pp. 103–7, 1902.

Several lakes were mapped, and the location of the headwaters of several rivers flowing to Lake Superior were determined. The explorations were carried through considerable territory hitherto unexplored.

Tyrrell, J. B. and D. B. Dowling. *Reports on the Northeastern Portion of the District of Saskatchewan and Adjacent Parts of the Districts of Athabasca and Keewatin.* Geol. Surv. Canada, Ann. Rept., Vol. XIII, Parts F and FF, 48 and 44 pp., 1902.

The report by Tyrrell covers explorations in Saskatchewan and Keewatin, while

that by Dowling extends also into Athabasca. Tyrrell's report is based upon an exploration in 1896 involving a trip of about 700 miles. Notes were made on topography and agriculture as well as the several geological formations. The recent and Pleistocene deposits are briefly treated under the topics: peat beds, shore lines, Pleistocene clay, eskers, till, kettleholes. The striæ of the Keewatin and the Labrador ice-fields are discriminated. Those in the western part were made entirely by the Keewatin, while those in the eastern part, with one or two exceptions, have been made by the Labrador ice-field. How far east the Keewatin ice field extended was not clearly worked out.

Dowling's report covers an exploration in 1899 and later visits. The encroachment of the Labrador ice-field on territory previously glaciated by the Keewatin is mentioned (p. 12.) The relation of the two ice-fields to Lake Agassiz is also briefly touched upon. The beaches in the northern part of the district belong to the later ones of Lake Agassiz, and it is inferred that the ice-sheet still occupied that ground while the earlier ones were forming. In the detailed discussion glacial and lacustral deposits along Saskatchawan River are first discussed, then the features about Moose and Cormorant Lakes and along Cowan River, and after this in turn the Menago, Burntwood River, Athapapuscow Lake, Kississing River and Lake, and Churchill River. The report is of especial interest because it extends into the territory near the limits of Lake Agassiz, though it does not work out fully the relationship of the lake beaches to moraines and other glacial features.

UPHAM, WARREN, *Toronto and Scarboro Drift Series.* Am. Geol., Vol. XXVIII, pp. 306–16, 1901.

The interglacial beds are interpreted to be part of a delta with a fan-like lakeward slope, which after being built up nearly 200 feet was deeply channeled by the same streams which built them, the change from building to channeling being brought about by the relief of the streams from much of their burden of silt. It is thought that the ice was close at hand all the time, and that the whole interglacial and subsequent glacial history is comprised in a few hundred or possibly a thousand years. (For a reply to this paper see Coleman, above.)

WILSON, A. W. G. *Physical Geology of Central Ontario.* Trans. Can. Inst., Vol. VII, pp. 139–86, 1901.

About half of this paper pertains to the older rock formations, but the latter half discusses the present topographic features and Pleistocene geology of that part of the province of Ontario lying north of Lake Ontario. The conclusion is reached that the main topographic features are preglacial, and that the work of the ice-sheet is restricted to the rounding off of pinnacles, small spurs, and outlying features. The Ontario lowland is thought to owe its origin to normal weathering, and erosion rather than glacial excavation. The main drainage, it is thought, may have led westward through the Dundas valley toward the Mississippi in a direction opposite to that advocated by Spencer (J. W.). Many of the tributary valleys are traceable, though greatly obstructed and concealed by the glacial deposits. (Summary taken from review by F. D. Adams in *Geologisches Centralblatt.*)

WILSON, A. W. G. *The Country West of Nipigon Lake and River.* Geol. Surv. Canada, Summary Rept. for 1901, pp. 94–103, 1902.

Seventeen small lakes and connecting streams were mapped and the rocks of the country examined. Chief attention is given to the hard-rock geology, but glacial

deposits are briefly discussed. The river valleys are more or less filled with sand and gravel occurring occasionally as eskers or kame-like mounds. There are also extensive bowlder-strewn plains. The country explored is regarded as a partly dissected tableland with a trap-capped cuesta.

WILSON, W. J. *Western Part of the Abitibi Region.* Geol. Surv. Canada, Summary Rept. for 1091, pp. 115–28, 1902.

Describes briefly streams, lakes, soils, topographic features, surface deposits, climate, and game, as well as the hard-rock geology.

UNITED STATES.

MAINE.

MANNING, P. C. *Glacial Potholes in Maine.* Proc. Portland Soc. Nat. Hist., Vol. II, pp. 185–200, 1901.

Describes the occurrence and character of the potholes along the coast of Maine and discusses the evidences indicating their origin. (Review by F. B. Weeks. Paper not examined.)

NEW HAMPSHIRE.

HITCHCOCK, C. H. *Interglacial Deposits in the Connecticut Valley.* Bull. Geol. Soc. Am., Vol. XII, pp. 9, 10, 1901.

Interglacial is not used in the customary sense, but has reference to deposits made in the midst of an episode of glaciation. Deposits underneath the eskers are called interglacial because they were formed earlier than the eskers. There are deposits of tough clay which have been contorted apparently by pressure induced by the overlying glacier. It is thought that the features support the view that a local Connecticut valley glacier succeeded an ice-sheet which had a general southeasterly movement.

VERMONT.

FINLAY, GEORGE. *Granite Area of Barre, Vermont.* Ann. Rept. State Geologist for 1902, pp. 46–8.

Describes sand plains and eskers in the vicinity of Barre, as well as the crystalline rocks. The features are thought to support the view that one esker at least is of subglacial rather than superglacial origin.

MASSACHUSETTS.

CLAPP, F. G. *Geological History of Charles River.* Tech. Quart., Vol. XIV, Nos. 3 and 4, 1901; also Am. Geol., Vol. XXIX, pp. 218–33, 1902.

An interpretation of the causes for the very devious course of the river is presented and the several stages of development discussed. A map sets forth the probable course of pre-glacial streams in the Charles River basin and vicinity. The retreat of the ice is supposed to have been such that a glacial lake was held in this drainage basin whose extent and whose outlets varied with the position of the ice-front The several distinct levels are discussed and named. These lake outlets control to some extent the course of the present river.

CROSBY, W. O. *Origin of Eskers.* Proc. Boston Soc. Nat. Hist., Vol. XXX, pp. 375–411, 1902; also Am. Geol., Vol. XXX, pp. 1–39, 1902.

Attention is first called to the evidence obtained from existing ice-sheets. The Malaspina glacier has often been referred to as affording examples of eskers in process of formation, but as only one esker has been found in the tracts recently abandoned by that glacier, it is thought that the deposits now being made in tunnels under the glacier will, when uncovered by the recession of the ice, be cut down by streams issuing from the ice or buried by detrital material. It is concluded, therefore, that the Malaspina glacier does not afford a good illustration of the way in which eskers were formed. The Greenland ice-sheet also is found to afford no good example of eskers in process of formation.

Eskers are generally admitted to be the product of a waning stage of glaciation in which the marginal zone of ice is practically stagnant. It is suggested that this stagnant portion may be partially overridden by newly formed ice, and thus material might be carried from lower to higher levels by a shearing motion. The superglacial hypothesis of the origin of eskers is favored by the author for the following reasons: (1) Their courses are to a marked degree independent of topography, and they will maintain their normal courses even if it leads them to forsake or to cross large valleys and rise to levels far above the other types of modified drift. (2) They seldom, if ever, occupy channels in either the bed-rock or till which are referable to the streams which formed the eskers. (3) The major and minor deviations or meanders of the eskers, as well as their general trend, seem hard to account for on the subglacial hypothesis, but are natural enough for superglacial streams. (4) The great length of eskers is thought to be consistent with subglacial stream action, but not with superglacial, for superglacial streams are limited in their length only by the breadth of the zone of ablation. It is difficult to believe in a tunnel of the great length of some eskers 100 to 150 miles, and such an explanation should be accepted only as a last resort. It is thought doubtful if crevassing would extend far back in continental ice-sheet to aid the subglacial work. (5) Double and reticulated eskers seem natural to superglacial streams, but not to subglacial, though Stone thinks these reticulations occurred where the subglacial stream became localiy superglacial. (6) The eskers are largely made up of distantly derived material, and differ from the underlying till, which is largely of local material.

The reviewer would call attention to the necessity either for qualifying or throwing out two of the above-mentioned reasons for favoring the superglacial origin of eskers. His observations in Ohio, Indiana, Illinois, and Michigan show that the channels, which under the second reason are said not to occur, are really present in the above-mentioned states, and are cut in the surface of the Wisconsin till. A description and map of one of these appears in Monograph XXXVIII, *U. S. Geol. Survey*, pp. 284–86, Pl. 14, 1899. The second point which the reviewer would make is that in the states just mentioned the eskers are very largely composed of local material, and have a constitution strikingly similar to the till which borders them. For notes concerning the proportion of local rocks both in eskers and till see Monograph XXXVIII, *U. S. G. S.*, pp. 78 and 286. Possibly the eskers of the states which the reviewer has examined, have had a different origin from those of New England, where the author's observations were made. The conditions in a very hilly or uneven country like New England may be different from those in the smooth districts in the states examined by the reviewer. Possibly in New England itself some eskers are of

superglacial and others of subglacial origin. (See paper by Finlay reviewed above, p. 606.)

CROSBY, W. O. *Hard-Packed Sand and Gravel.* Tech. Quart., Vol. XV, pp. 260–64, 1902.

At certain points in the Nashua valley near Clinton, Mass., deposits of sand and gravel are found which are very difficult to penetrate with the drill. An examination of samples shows that scaly fragments of schist, mica, etc., form a notable constituent in some cases, but in others the material consists very largely of angular or subangular quartz fragments. Upon experimenting with the latter under various conditions of water admixture it has been found that where there is insufficient water to fill the pores the surface tension of the water causes it to act as a cement binding the grains together, and it is thought that this affords a solution of the cause for the "hard-packed" material noted in the Nashua valley.

DAVIS, W. M. *River Terraces in New England.* Bull. Mus. Comp. Zoöl., Harvard College Geological Series, Vol. V, No. 7, pp. 278–346, 1902. Abstract published in Bull. Geol. Soc. Am., Vol. XII, pp. 483–85, 1901.

The control exerted by rock ledges or other resistant material on certain river terraces of New England is discussed in some detail, and attention is called to the bearing on the interpretation of terraces that heretofore had been referred to gradation with respect to temporary base levels. It is also shown that the arrangement of terraces in flights of steps does not depend on the stream volume, however true it may be that the stream volume has diminished during the process of terracing.

DAVIS, W. M. *Terraces of the Westfield River, Massachusetts.* Am. Jour. Sci., 4th series, Vol. XIV, pp. 77–94, 1902.

The Westfield River is taken as a good illustration of the effect of resistant obstacles in developing terraces. (See previous paper.)

FULLER, M. L. *Probable Representatives of pre-Wisconsin Till in Southeastern Massachusetts.* Jour. Geol., Vol. IX, pp. 311–29, 1901.

The supposed pre-Wisconsin till is of a very different type from the ordinary till of that part of New England. It contains about four times as much clay, and only about one-fourth the per cent. of coarse rock fragments and pebbles found in the ordinary till. In its composition a more striking dependence on the underlying rock formations is shown, and its material is also more highly oxidized than the overlying till, and often differs from it strikingly in color. Aside from the exposures noted, which are near Brockton and Stoughton, there are numerous exposures in which pre-Wisconsin age is suspected from the advanced stage of weathering of the rock fragments in the till.

HOLLICK, ARTHUR. *Reconnaissance of the Elizabeth Islands.* Ann. N. Y. Acad. Sci., Vol. XIII, pp. 387–418, Pls. VIII–XV, 1901.

The islands are composed largely of a bowldery moraine, which has points reaching altitudes of 125–150 feet above the sea, though the greater part is much lower. The moraine is thought to be a portion of the later or northern branch of the terminal moraine on Long Island, and is more recent than the moraine on Marthas Vineyard, Block Island, and Montauk Point. Considerable attention is given to the vegetation, and especially the forestry conditions.

JEFFERSON, MARK S. W. *Limiting Width of Meander Belts.* Nat. Geog. Mag., Vol. XIII, pp. 373–84, 1902.

The small Matfield River of Massachusetts was made a subject of special study, and the results are compared with published results on the moderate-sized Oder and the great Mississippi River, for each stream has meanders on its flood plain. The data concerning a few rivers having incised meanders are then examined and found to be insufficient to establish definite relations, though it is thought that the discordances might be removed by more detailed studies. The mean meander ratio is found to be 17. 6 : 1; that is a meander belt is that many times the width of the stream.

JULIEN, ALEXIS A. *Geology of Central Cape Cod.* Am. Geol., Vol. XXVII, pp. 44, 1901.

Discusses the glacial formations with special reference to the district from Chatham to Yarmouth. Attention is called to the intercalation of clays in the stratified deposits south of the morainal backbone of the Cape which have suffered some disturbance and flexure. Kettle-shaped hollows and pond basins are discussed in their relation to preglacial drainage valleys. Attention is also given to changes of level.

JULIEN, ALEXIS A. *Erosion by Flying Sand of the Beaches of Cape Cod.* Abstract Ann. N. Y. Acad. Sci., Vol. XIV, pp. 152, 1901.

Not examined.

WILSON, A. W. G. *The Medford Dike Area.* Proc. Boston Soc. Nat. Hist., Vol. XXX, pp. 353–74, 1901.

The discussion relates mainly to the crystalline rocks, but the glacial phenomena of the region are briefly described.

CONNECTICUT.

HOBBS, W. H. *An Instance of the Action of the Ice Sheet upon Slender Projecting Rock Masses.* Am. Jour. Sci., 4th series, Vol. XIV, pp. 399–404, 1902.

Discusses the abrading effect of the ice-sheet on slender masses of projecting rock along the bluffs of the Pomperaug valley of Connecticut, and trains of bowlders resulting therefrom.

NEW YORK.

FAIRCHILD, H. L. *Pleistocene Geology of Western New York.* Twentieth Rept. of State Geologist for 1900, pp. 103-39 Pls. 9–41, 1902.

The results of a special study of the Iroquois shore line between Richland and Watertown, N. Y., are first presented. The chief attention is given to the rate of differential elevation of the beach, though its constructional features are mapped in some detail. This study seems to support the conclusion that the warping of the eastern end of the Ontario basin has mostly, if not entirely, taken place since the extinction of Lake Iroquois, for the entire eastern shore seems equally tilted. The large amount of tilting considered in connection with the usual estimates of post-glacial time (10,000 to 50,000 years) would indicate that the rate of deformation has been much greater than the present rate of 0.42 foot in 100 miles in 100 years, estimated by Gilbert.

A study of the territory between Syracuse and Oneida with special reference to the higher and earlier channels cut by the overflow of the glacial waters is illustrated by a large number of photographs showing the features of these channels and of cataract basins and ancient deltas along them. The retreat of the ice being westward in this region, the eastern channels are older than the western, and they were apparently formed in regular succession westward.

A reconnaissance in the Cattaraugus-Chautauqua district along the divide between the Ohio and Lake Erie drainage throws light upon the character of the glacial drainage. Few channels cross the divide, the only important one being at Persia Siding, where waters passed from the Cattaraugus to the Conewango drainage basin. Most of the channels which drain southward head in uncut morainic drift. The explanation is found in the fact that there was southwestward escape along the ice-front for the glacial waters of this region as soon as the ice had receded a little from the divide. Several channels representing successively lower levels taken by waters draining a lake in the Cattaraugus basin westward along the ice-front into the Erie basin are described in the eastern portion of their course in the vicinity of Gowanda, but were not traced westward their entire length. The report closes with a brief description of drumlinoidal aggregations of drift near the head of Lake Chautaugua.

GRABAU, A. W. *Guide to the Geology and Paleontology of Niagara Falls and Vicinity (with a Chapter on Post-Pliocene Fossils*, by ELIZABETH LETSON). Bull. 45, New York State Museum, 284 p., 1901.

The introduction deals with the best routes for viewing the Falls region. Chap. 1 discusses the physical geography of the region and chap. 2 the life-history of the Falls, while chaps. 3 and 4 discuss the stratigraphy and fossils of the hard-rock formations, and chap. 5 (by E. J. Letson) the post-Pliocene fossils. The bibliography of ten pages forms an appendix, and this is followed by a glossary of fourteen pages. This guide-book affords a comprehensive interpretation of the region, presenting the results of the various workers in that field as well as the author's contributions and interpretations.

Certain parts of the interpretation of the drainage development are extremely hypothetical, and in the reviewer's opinion somewhat doubtful. For example, the eastern end of the Ontario basin is represented to have drained southward in Tertiary time through the Genesee (reversed). The view that the drainage of the Ontario, Erie, and Huron basins was southwestward toward the Mississippi seems to be in harmony with the latest results obtained in Michigan, though it can hardly be considered well established. The drainage of the Ontario and Erie basins toward the Mississippi in Tertiary times seems, however, to be a good working hypothesis.

GILBERT, G. K. *Summary History of Niagara Falls.* Published with topographic map of Niagara, U. S. Geol. Survey, 1901; reprinted in Am. Geol., Vol. XXVII, pp. 375–77, 1901.

As the title implies, the several events in the history of this region are briefly outlined. The St. David's channel is referred to without question as an interglacial gorge, and it is also stated that there were two times when the upper Great Lakes discharged by other lines than the Niagara River for periods of considerable length. These diversions make it necessary to lengthen the estimates of time required to excavate the gorge beyond that necessary for a continuous stream of the present capacity.

It is considered a matter of doubt whether the time is expressible in tens of thousands or in hundreds of thousands of years.

HITCHCOCK, C. H. *The Story of Niagara.* Am. Antiquarian, Jan., 1901.

The geological history is reviewed and the leading views concerning the falls themselves are briefly presented. It is estimated that the time since water began falling over the Niagara escarpment is 18,918 years, distributed as follows: Erosion of lower gorge below the cove, 6,844 years; erosion of the cove section, 937 years; erosion of the gorge of the whirlpool rapids, 7,800 years; erosion from the railroad bridges to the existing cataract, 2,962 years. In addition to this 475 years is estimated for the wearing out of the whirlpool basin.

MARTIN, J. O. *The Ontario Coast between Fairhaven and Sodus Bays, New York.* Am. Geol., Vol. XXVII, pp. 331–334, with map, 1901.

Describes the encroachment of the shore of Lake Ontario upon the drumlins and the building of beaches between the drumlins with materials cut from them. The shore has advanced at least one-fourth to one-half mile since the lake has had its present level, and the rate of cutting varies from a few inches to ten feet a year.

OGILVIE, I. H. *Glacial Phenomena in the Adirondacks and the Champlain Valley.* Jour. Geol., Vol. X, pp. 397–412, with map, 1902.

Striæ indicate that the Champlain–Hudson valley ice-lobe spread southwestward into the Adirondacks, and there appears to be no change in direction resulting from differences in altitude. There was very little scouring by the ice in the valleys of the interior of the Adirondacks. Variations in the glaciation are separable into three zones: (1) a zone of abundant striation, though variable bearing, along the Champlain valley; (2) a zone along the gneissic hills in which striæ are not numerous, but are uniform in bearing (northeast–southwest); (3) a zone among the high anorthosite peaks where striæ are lacking, but the mountain tops are smooth.

The glacial deposits are largely of stratified material. A glacial lake which occupied the Champlain valley has its shores marked by large delta accumulations at each of several lake levels. This glacial lake was followed by an incursion of the sea, which brought in a marine fauna.

There appears to have been a glacial gathering ground in the interior of the Adirondacks late in the Glacial epoch, and its local glaciers built up small moraines across a few valleys.

The drainage lines were begun far back in geologic time. The lakes are generally partially filled preglacial valleys, broadened perhaps by ice action.

SALISBURY, R. D. *New York City Folio, Pleistocene Formations.* Geol. Atlas of the United States, U. S. Geol. Survey, Folio No. 83, pp. 11–17, 1902.

The four fifteen-minute quadrangles in the New York City Folio are covered by glacial deposits and glacial outwash except a small driftless tract of scarcely one square mile near New Dorp on Staten Island. On this driftless tract is a gravel deposit of late Pliocene or early Pleistocene age which is referred to the Beacon Hill or Bridgeton formation. Gravel of the Pensauken formation is exposed under glacial deposits in clay pits around Kreisherville, Staten Island, and by the waves in the cliff

at Princess Bay Light. The Pensauken is thought to be no older than some of the glacial deposits, though not of glacial origin.

The growth of the ice-sheet, the recurrent glaciations, and the characteristics of glacial drift are briefly discussed before taking up the features and deposits found within the New York area. The topography, topographic relations, and composition of the moraine on Staten and Long Island, the stratified drift south of the moraine, and the ground moraine to the north, are discussed in some detail, after which striæ, mixed drift, and stratified drift north of the moraine are considered, and attention is called to a surface loam, which, it is thought, may have originated in several different ways. Gravel near Rockaway on Long Island, though nonglacial, is thought to be of late Glacial age or even younger, and is correlated with the Cape May formation. The oscillation of the land, stream erosion, shore erosion, and weathering in postglacial time are then considered. The evidence concerning land oscillation is found to be indecisive. The slight amount of weathering of the drift surface, of stream erosion, and shore erosion testify to the briefness of the postglacial epoch.

STEVENSON, A. E. *Glacial Action in Schoharie Valley.* Ann. N. Y. Acad. Sci., Vol. X, 1901.

Not examined.

UPHAM, WARREN. *Preglacial Erosion in the Course of the Niagara Gorge and its Relation to Estimates of Postglacial Time.* Am. Geol., Vol. XXVIII, pp. 235–44, 1901.

The St. David's channel is thought to be preglacial rather than interglacial, because of its wide mouth. Fish Creek, a small eastern tributary of the Niagara, entering just south of the Niagara Escarpment, is thought to be occupying a preglacial valley which continued in the course of the Niagara River (reversed) to connect with the St. David's channel at the whirlpool. This would render but a small amount of rock excavation necessary in opening a part of the gorge below the whirlpool, and would materially affect estimates of the length of postglacial time. On the assumption that much of the northward differential uplift followed very closely upon the ice retreat (an assumption which Fairchild's observations at the east end of Lake Ontario show to be unfounded for that region) Upham concludes that the three upper lakes could not have discharged through either the Trent or the Mattawa valley, and considers the erosion of the Niagara gorge the work of a stream whose volume never was much less than the present and for the early part of the erosion was much greater. From this it is reasoned that postglacial time has been very brief, 7,000 years being considered ample for that part of it involved in cutting the Niagara gorge.

WOODWORTH, J. B. *Pleistocene Geology of Portions of Nassau and Queens Counties, New York.* Bul. 48, N. Y. State Museum, pp. 53, 1901.

This bulletin is the first of a series which is planned for the discussion of the Pleistocene geology of the eastern part of New York. It embraces a discussion of topographic features, glacial deposits, Pleistocene history, and postglacial changes and processes now in action, but deals mainly with the Pleistocene deposits.

The topographic features embrace a morainic system with two ridges separated by a sand plain, and south of this morainic system an extensive outwash plain sloping from a morainic border to the sea. North of the morainic system is a tract of uneven

drift, coated generally by till, but having thick deposits of sand and gravel underneath the till.

The glacial deposits exhibit three marked phases of Pleistocene history: (1) a group of old gravels and sands with an intercalated till bed, the group considered to be the equivalent of the Columbia formation of the Atlantic coastal plain; (2) a deglaciation interval with marked erosion; (3) the moraines and their attendant stratified gravels and sands of Wisconsin age forming the topographic details of the surface.

No decisive local evidence was found concerning the relation of land to sea-level during the deposition of the old gravels and sands, but subsequent to deposition they appear to have been channeled by open-air streams. In the subsequent ice advance the land appears to have been as high as now, if not higher. During the retreat of the ice temporary lakes existed back of the moraine, one of which stood at 80 feet above sea-level, and its successor at a lower level. Possibly the lower body was at sea-level. Glacial action ceased with the retreat of the ice across East River. The streams on the outwash plain south of the moraine flow in courses which appear to have been carved by the more vigorous glacial streams, while those on the north slopes are, in some cases, apparently in partially filled interglacial channels. Modern marine action has encroached on the south edge of the outwash plain and thrown bars of sand and gravel across the old glacial stream channels. There are two lines of evidence pointing to a sinking of the coast in recent time, one being the occurrence of peat beds below present sea-level, the other the absence of wave cutting at present sea-level on points which stand back of the recently formed barrier beaches.

WRIGHT, G. F. *The Rate of Lateral Erosion at Niagara.* Am. Geol., Vol. XXIX, pp. 140–43, Pls. 6–8, 1902.

Measurements of the amount of crumbling and recession of the shale portion of an unprotected part of the wall of the Niagara gorge from 1854–1898 indicate a marked change, the average of fifteen measurements in the Clinton Shale showing extreme erosion of 3 inches per year, and the average of eleven measurements in the Niagara Shale 3¼ inches per year. Taking the entire exposed face into consideration, the average rate for the Clinton and Niagara shales is estimated to be 1½ inches per year. As these are unprotected by talus or vegetation, the allowance of such protection was estimated, and is thought to possibly reduce the rate of recession of the walls of the gorge to one-seventh that of an unprotected slope, but not more. This would give one-fourth inch per year, which is all that would be necessary to accomplish the actual enlargement of the mouth of the Niagara gorge in 10,000 years, and that is what the author set out to demonstrate by these measurements.

NEW JERSEY.

SALISBURY, R. D. *The Glacial Geology of New Jersey.* Final Report of State Geologist, Vol. V, xxiii, 802 pp., 66 Pls., and 102 figs. in the text, Trenton, 1902.

The volume consists of two parts, a general discussion and a discussion of the local details. In the general discussion the glacial formations and questions pertaining to glaciation are taken up. It differs from the author's papers already published in the JOURNAL OF GEOLOGY in containing numerous references to the glacial deposits

of New Jersey. It is such a presentation of glacial geology as will be of much use in class work in universities and colleges, and at the same time is of interest and easy comprehension to the general reader. The reviewer hesitates to refer to certain misleading statements (which appear on pp. 183–86) in a work which otherwise is so accurate and comprehensive. The Iowan drift is but little more weathered and eroded than the Wisconsin, and cannot be separated from it by the long interval mentioned in this report. The Illinoian drift-sheet which in this report is doubtfully admitted to rank with the Kansan, Iowan, and Wisconsin, really marks the culmination of the Labrador ice-field, and is no more due to a local advance than is the Kansan drift-sheet which marks the culmination of the Keewatin icefield.

The discussion of local details opens with a description of the terminal moraine of the Wisconsin drift-sheet throughout its course across New Jersey, after which are considered in turn the drift of the Appalachian province, of the Highlands, and of the Triassic plain, in each of the several phases which are exhibited. Recessional moraines were traced for short distances in the Appalachian province and in the Triassic plain, but the tracing was not carried far enough to bring out, as has been done in states west of the Appalachians, the successive positions of the ice-border in its retreat. It appears from the scant notice given these later moraines that they constitute very inconspicuous features. After discussing the drift north of the terminal moraine, the stratified drift of late glacial or Wisconsin age lying south of the moraine is considered. It includes not only valley gravel and overwash gravel plains, but also lacustrine clays and silts, subaqueous overwash, kames, and certain deposits attributed to icebergs.

An old sheet of extra morainic drift, which has been described somewhat fully in the *Reports of Progress* for 1892 and 1893, is briefly considered in this final report. It is found to be discontinuous or patchy, and in this respect is strikingly in contrast with the drift-sheet north of the moraine. It is estimated that about four-fifths of the surface north of the moraine is deeply covered with drift, while about the same proportion south of the moraine is nearly destitute of drift. In lithological make-up the extramorainic drift is not greatly different from the drift in and north of the moraine. But much of it is more highly oxidized and weathered than the moraine and drift-sheet to the north. It is thought that the most highly weathered drift is at least as old as the Kansan drift of the western states.

MARYLAND.

SHATTUCK, GEORGE B. *The Pleistocene Problem of the North Atlantic Coastal Plain.* Johns Hopkins Circulars No. 152, May, 1901; also Am. Geol., Vol. XXVIII, pp. 87–107, 1901.

Results of studies by McGee, Darton, and Salisbury are reviewed and attention called to lack of harmony in the interpretations, and to changing views that have been advanced. The author fails to find evidence of such complexity as his predecessors have discovered, and considers the simple interpretation of marine action at different levels sufficient to account for all the phenomena. Certain features which one of his predecessors had interpreted to be unconformities pointing to a period of elevation and subaerial erosion the author thinks to be due to slight changes in current or freshet conditions differing in no way from the ordinary cross-bedded structure. An excursion into New Jersey confirmed the author in his view that the simple

interpretation of marine action furnishes as complete a solution there as in Maryland, and he expects this interpretation ultimately to find application over much of the Atlantic coastal plain.

WEST VIRGINIA.

CAMPBELL, M. R. *The Huntington Folio.* Geol. Atlas of the United States, U. S. Geol. Survey, Folio 69, 1901.

Drainage and Pleistocene deposits are the topics pertinent to this review. The Huntington Quadrangle includes several streams with an unsymmetrical arrangement in their respective basins, which is explained by tilting. This quadrangle includes also a part of the well-known Teazes or Teays valley, the former course of Big Kanawha River. The diversion of the river into its present course is referred to an ice-gorge near Milton, and so is the heavy accumulation of silt in the abandoned valley, which is here given the name Teay formation. The gorging is thought to have been accomplished by river ice concurrent with the culmination of glaciation in the adjacent part of the glaciated region. The same ice gorge is thought to have caused Hurricane Creek to continue northward past Teays valley in a course parallel with that of the diverted Kanawha. An ice-gorge on Guyandotte River near the Lincoln-Wayne county line is thought to have diverted the stream to a course a short distance east of the old one. This river sustained another diversion near its mouth in passing across Teays valley, which, however, is not mentioned. In support of the view that these diversions were caused by ice-gorges, the smaller amount of silt below the site of the supposed gorging in Teays valley is brought forward. The reviewer, however, doubts whether there was a smaller deposition in this valley below the site of the supposed gorge than above. There is still a heavy deposit in part of this lower course near where the Guyandotte River has been diverted, and Mud River has apparently removed much of the silt between there and Milton. The value and applicability of this new hypothesis remains to be determined. In Monograph XLI, *U. S. Geological Survey* (pp. 105, 106), the reviewer called attention to the fact that the silting was sufficient to build the valley up to a level as high as low cols in the district north of it, thus making it possible for a stream to take a new course without having to open a channel.

The Teay formation or silt deposit which graded up the old course of the Big Kanawha is a fine deposit overlying coarse material such as commonly characterizes river beds. It has a depth of about sixty feet where best preserved from erosion, as is the case near Hurricane village.

New Ichthyosauria from the Upper Triassic of California. By J. C. MERRIAM. University of California Publications, Bulletin of the Department of Geology, Vol. III (1903), pp. 249–63, Plates XXI–XXIV.

THE interesting discoveries made by Dr. Merriam, during the past few years, of many new and strange forms of Ichthyosauria from the Californian Triassic have added much to our previous knowledge of this remarkable order of reptiles. To the six species of *Shastosaurus*

previously described by the author two new genera, *Leptocheirus* and *Torotecnemus*, are added in the present paper. The limbs in these forms are of strangely primitive structure, in some respects. The propodial and epipodial bones are elongated, and there are but three digits, with a rudimentary or vestigial fourth. The hind limbs are also larger than the fore limbs, in some at least; and the ribs of the dorsal region in some of the species are single-headed. The author promises us the description and illustration of still other and divergent forms soon, and, from the thoroughness with which he is studying his abundant material, we may confidently expect much new light upon the history of this strange, and in many respects puzzling, order of reptiles.

S. W. W.

On the Skull of a True Lizard (Paliguana Whitei) from the Triassic of South Africa. By R. Broom. Records of the Albany Museum, Vol. I, p. 1.

Hitherto the mesozoic history of the Squamata, aside from the Dolichosauria and Mosasauria, has been very scanty indeed. The discovery by Broom of what is undoubtedly a real lacertilian from the Triassic is, therefore, of more than passing geological interest. The author believes that its relationships are close with the American Iguanas. The teeth are apparently pleurodont, the quadrate is free, and the upper temporal arch has the disassociated elements of the lacertilia. With this addition to the Triassic fauna, all the known orders of reptiles are now represented in this formation, as also the mammals.

S. W. W.

Recent Publications.

—Adams, George I. Stratigraphic Relations of the Red Beds to the Carboniferous and Permian in Northern Texas. [Bull. Geol. Soc. of Am., Vol. XIV, pp. 191–200; Rochester, May, 1903.]

—Bell, Alexander Graham. The Tetrahedral Principle in Kite Structure. [Reprinted from the National Geogr. Mag., June, 1903.]

—Biddle, H. C. The Determination of Molecular Weights. [Reprinted from Amer. Chem. Jour., Vol. XXIX, No. 4, April, 1903.]

—Coste, Eugene. The Volcanic Origin of Natural Gas and Petroleum. [Paper read at annual meeting of Canadian Mining Institute, Montreal, March 4 and 5, 1903; Ottawa, 1903.]

—Davis, W. M. An Excursion to the Plateau Province of Utah and Arizona. [Bull. of the Mus. of Comp. Zoöl., Harvard College, Vol. XLII; Cambridge, June, 1903.]

—Diller, J. C. Klamath Mountain Section of California. [Am. Jour. of Sci., Vol. XV, May, 1903.]

—Fuller, M. L., and Clapp, F. G. Marl-Loess of the Lower Wabash Valley. [Bull. G. S. A., Vol. XIV, pp. 153–76; Rochester, April, 1903.]

—Grant, Ulysses S. Preliminary Report of the Lead and Zinc Deposits of Southeastern Wisconsin. [Wis. Geol. and Nat. Hist. Surv., Bull. IX, Economic Ser. No. 5; Madison, 1903.]

—Hobbs, William Herbert. Meteorite from Algoma, Wisconsin. [Bull. Geol. Soc. of Am., Vol. XIV, pp. 97–116; Rochester, April, 1903.]

—Kindle, Edward M. The Niagara Domes of Northern Indiana. [Am. Jour. of Sci., Vol. XV, June, 1903.]

—Kotô, B., and Kanazawa, S. A Catalogue of the Romanized Geographical Names of Korea. [Imperial Univ. of Tôkyô, Japan, 1903.]

—Lee, Willis T. The Canyons of Northeastern New Mexico. [Reprinted from Jour. of Geogr., Vol. II, No. 2, February, 1903.]

—Ordóñez, Ezequiel. El Sahcab de Yucatan. [Imprinta de le Gobierno Federal en el ex-Arzobispado; Mexico, 1903.]

——— Le Xinautecatl on Volcon Nevado de Toluca. [Imprimerie du Gouvernement Fédéral, Mexico, 1903.]

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